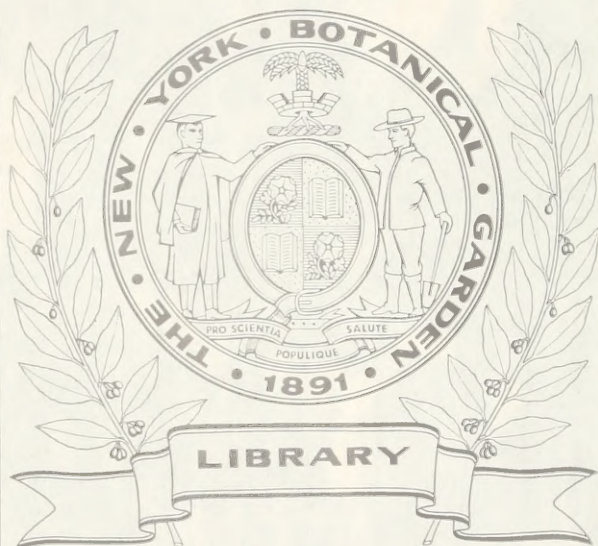






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JANUARY, 1916

**ALABAMA**  
**Agricultural Experiment Station**

OF THE

**Alabama Polytechnic Institute**

**AUBURN**

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**Cabbage**

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By

J. C. C. PRICE, Associate Horticulturist

and

G. V. STELZENMULLER, Field Agent in Horticulture

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# CABBAGE

By

J. C. C. PRICE, Associate Horticulturist

AND

G. V. STELZENMULLER, Field Agent in Horticulture.

This bulletin contains the results of several years' experiments with cabbage; together with general cultural directions based upon the experiments. The cultural suggestions will not hold equally true in all sections of the state, but the fundamental principles are applicable to these different sections.

## TIME OF SOWING SEED.

Cabbage, if properly hardened, will stand temperatures as low as 15 degrees above zero for brief periods. As a rule, therefore, in Alabama, cabbage grown from seed sown in October and transplanted to the field can easily be carried through the winter, and at the same time will make considerable root growth. The proper time for sowing the seed is from the middle of October to late spring. Plants produced from seed sown prior to the first of October are prone to run to seed in the early spring, instead of heading. Several times at the Experiment Station here, seed was sown as early as the last week in August, with the result that more than 50 per cent of the plants ran to seed. Sowing the seed too early gives the plant an equivalent of two growing seasons. Cabbage is a biennial. Sowing seed early in the fall gives the plant a period of active growth. The advent of cold weather then abruptly checks growth, introducing a period of rest, which practically marks off the equivalent of one season's growth. On resuming growth in the spring, the tendency is to set about seeding instead of the formation of a head.

## SEED.

Great care should be exercised in securing the best seed, as the best is none too good. One may purchase poor seed with the view of saving a small sum, and on the other hand lose several hundred times that amount in the crop. It is essential that the seed be fresh, vigorous, of a pure strain and true to type, in order to



produce an early maturing crop, and be harvested in two cuttings.

#### THE SEED BED.

In the southern portion of the state large seed-beds are prepared in the open, while in the northern part of the state cold frames or hot-beds are used. If the seed-bed is prepared in the open it should be made in a new place each year. For the hot-bed, select an elevated place where drainage is good. A southern or southeastern slope is preferable, with a fence or building, when possible, on the north or northwest as a windbreak. A pit should be dug 10 or 12 inches deep, 6 feet wide, and long enough to accommodate as many plants as desired. Construct a frame of good heart lumber,  $1\frac{1}{2}$  to 2 inches thick. The board for the back should be 14 inches wide, and the one for the front 8 inches wide, with the end pieces sloping to fit. The frame should fit into the place excavated, resting on the manure. Strips of 2x4 inch material are nailed across the frame at intervals of three feet, to hold the sash. The standard sash is 3x6 feet in size, exclusive of the drip board at the foot, which projects a few inches beyond the side of the frame on the lower side. The excavation should be filled with fresh stable manure, which has been thoroughly moistened and mixed. It should be reworked each day until it heats uniformly. It is then leveled, packed down firmly and a layer of dark, rich sandy loam soil is put on top of the manure to the depth of 4 inches.

It would be rather troublesome to move the cold frame or hot-bed, so the best method would be to fill the frame with new soil each season. The soil should be taken from an area on which neither a crop nor a seed-bed of cabbage or any species of the cabbage family has grown for several years. One should take this precaution as a safeguard against disease.

The soil used for the seed-bed should be of a light, loamy character, fairly rich, and one that will not bake. It should be thoroughly pulverized, and all rocks sticks, and trash of any kind should be removed. The seed may be sown broadcast or in close drills, the latter being commonly preferred. The drills are made by using a narrow board with a straight edge. The edge of the board is pressed into the soil so as to make a furrow about three-fourths of an inch deep. Sow the

seed thinly in the furrow, and pack the soil lightly, covering the seeds from  $\frac{1}{2}$  to  $\frac{3}{4}$  of an inch deep. As the plants break through the soil they will be greatly benefited by a light stirring of the soil along the rows. When they have put on the third leaf, or first real leaf, they should be transplanted into another bed into rows farther apart, and given at the same time more space in the rows. Four inches between rows and two inches in the rows will be ample. This transplanting enables the plants to grow more stocky, and makes them form a better root system. The plants remain in the second bed or frame until large enough to set in the field.

Plants produced under sash in mid-winter have to be hardened off before planting in the field. Grown in a hot-bed or cold frame and protected by sash, plants are quite tender when young, but may be gradually hardened to stand severe weather. To "harden off" plants, remove the sash entirely on warm days and wholly or partially close the bed at night. From day to day accustom the plants gradually to the open air, until at last the sash is left off entirely. Should there be a sudden drop in the temperature during the hardening-off period, the sash should be pushed over the frame and propped up slightly at the ends, allowing the air to pass under the sides. If properly handled, the plants can be made tough enough to plant in the field in from ten to twenty days.

#### SOIL.

Cabbage will grow in any fairly good soil, from a light sandy to a rich alluvial bottom land, but a rich loam with a good porous clay subsoil is to be preferred. By incorproating sufficient organic matter, poor soils may be made to produce excellent crops. Unless the soil is carefully broken and prepared, good results can not be expected. One should use a good two-horse turning or disc plow, running deep enough to turn up about an inch of the clay subsoil. If the subsoil be hard, or there is found a hard-pan, fall-breaking in connection with the use of a subsoil plow is desirable.

Further preparation consists in thorough harrowing with a spiked-tooth or disc harrow until the surface is thoroughly pulverized. Lay off rows 3 to  $3\frac{1}{2}$  feet apart, using a shovel plow and opening out a good



furrow. The fertilizer should be strewn along in the furrow at the rate of 1,000 to 1,500 pounds per acre. Mix thoroughly with the soil by running the shovel plow in the furrow one or more times. One time will be sufficient if the soil is very loose. List on the furrows in which the fertilizer is distributed, throwing up a small ridge. Flatten the top of this ridge with a hand rake or drag a heavy piece of timber over the rows, leveling several at a time. General preparation of the land should be in the fall or at least several weeks before planting. If the land is prepared early, delay by the heavy winter rains when ready to plant may be prevented.

#### PLANTING.

The time to plant will vary greatly for the different sections of the state. Plants will be ready to set in 5 to 7 weeks from the time the seed is sown. They should be set on the south side of the ridge or bed thrown up by the shovel plow, in preference to planting on top, as this gives protection from cold northwest winds. Set plants from 15 to 24 inches apart in the row, according to the variety. The small pointed-head varieties will permit much closer planting than the large flat-head types. If the field be level, it is preferable to check the rows, so as to allow horse cultivation both ways. The check rows are 24 to 30 inches apart.

With proper precautions, the plants may be transplanted to the field with very small loss. Plants should not be transplanted on windy days, as the excessive evaporation will result in a heavy loss of plants. A still, cloudy day is best, or late in the afternoon. Transplanting should not be done unless there is plenty of moisture in the soil; otherwise moisture should be supplied artificially. Transplanting is best accomplished by one person dropping the plants, and another with a dibble setting them out as they are dropped. The plant bed should be thoroughly watered before taking up the plants. If they are to be carried some distance the roots should be dipped in a clay puddle, which will prevent them drying out. A piece of wet sheeting spread over the plants in the basket or tray, will aid in keeping them in a fresh condition. A few plants are taken at a time and set as they are dropped, in order that they may be protected as much as possible.

## CULTIVATION.

Surface tillage may begin at once, or at least as soon as the plants have had time to establish themselves in the soil. The small tooth cultivator is the best implement, as it cultivates shallowly and finely. By running this implement twice in each middle at intervals of a week or ten days, a good, mellow mulch will be maintained. This aerates the soil and conserves moisture and also keeps down weeds. Where the rows are not laid off both ways, the hoe should be used to break up the crust between the plants and to pull a little soil to any plants that need it. The hoeing or cultivation should be frequent and thorough, but not deep, and should be continued until the plants are fairly well headed.

## FERTILIZERS.

Cabbage soil can hardly be made too rich, but the plant food materials should be in a well balanced form. When possible a liberal application of stable manure or a green crop should be turned under in the fall previous to planting. Sufficient quantities of animal manures cannot always be secured, neither may green crops be available at the time. Commercial fertilizers must then be used instead. If used at planting time, the formula should have a reasonable quantity of phosphoric acid and potash, but not the full amount of nitrogen, that will ultimately be needed. When the plant is small it can use only a limited amount of nitrogen, while the remainder of the application might be leached out and lost. When nitrogen is applied to the soil it stimulates a succulent leaf growth. Hence, much nitrogen tends to make the young plants too tender to stand severe freezing weather. If made to grow slowly, cabbage plants will stand a temperature as low as 12 degrees F., the lowest temperature recorded at the Experiment Station during the test. Since, in maturing the cabbage crop, it is leafy growth we desire, nitrogen is necessary in the fertilizer, but most of it should be applied at the approach of the growing season rather than at planting time.

For use in the furrow at planting time let the fertilizer be what is known as a *complete* fertilizer. Such a fertilizer may be made up as follows:



|                         |            |
|-------------------------|------------|
| Acid phosphate .....    | 437 pounds |
| Nitrate of Soda .....   | 375 pounds |
| Muriate of Potash ..... | 180 pounds |

Apply at the rate of at least 1,000 pounds per acre. If there has been much leaching due to heavy rains during the winter, a second application of 400 to 500 pounds per acre of a complete fertilizer should be given several weeks later.

At the approach of the growing season, which will vary considerably in the different sections of the state, the plants should be stimulated by a side or top dressing of 75 to 100 pounds of nitrate of soda per acre. If the plants are slow about heading the top-dressing of nitrate of soda should be repeated in 15 to 20 days. Care should be exercised in the use of nitrate of soda, as an excess will cause the formation of a succulent head which will not hold up well in shipping. On the other hand, the use of potash tends towards firmness.

#### FERTILIZER EXPERIMENTS.

The table below gives some results of experiments with fertilizers at Auburn.

The complete formulas, except for Plot 4, were made up so as to analyze seven per cent. phosphoric acid; six per cent. nitrogen; and nine per cent. potash. The mixtures were applied at the time of planting, at the rate of 1,500 pounds per acre.

Formula 4 was made up of low grade materials, and contains 54½ per cent. phosphoric acid, 4½ per cent. nitrogen, and 6½ per cent potash, but it was applied in excess to give the same number of pounds of actual fertilizing material used in the three formulas above.

Acid phosphate and Thomas phosphate were compared, as shown on plots 3 and 5. The average for two years shows a difference in yield of 6,216 pounds per acre in favor of Thomas phosphate. Plot 5 which received the Thomas phosphate, produced the highest yield of any of the plots receiving complete fertilizers.

Note the difference in the source of nitrogen in Plots 1, 2, 3, and 4.

Plot 3, with nitrate of soda as the source of nitrogen, gave highest average yield with the highest average increase over unfertilized plot, the other ingredients being the same in kind and quantity, except slight differences seen in Plot 4. This Plot, with cotton seed

meal as the source of nitrogen, gave second highest yield with second highest increase.

Plot 1, with sulfate of ammonia as the source of nitrogen, gave an average yield of 679 pounds of cabbage per acre less than cotton seed meal (Plot 4.)

Plot 2, with dried blood as the source of nitrogen, gave the lowest average yield of the complete fertilizers, but an increase of 10,753 pounds of cabbage per acre over the unfertilized plot.

Observe that the omission of potash in Plot 6 did not decrease the yield as compared with Plot 2, where a complete formula was used. While in Plot 10, where potash was used alone, the average increase for two years was only 707 pounds per acre over the unfertilized plot.

Comparing results on plots 8, 9, 10, 11, and 12, where the several fertilizer ingredients were used singly, dried blood gave the highest average yield with the highest average increase over the unfertilized plot.



Figure 1.

On right of basket, fertilized plot.

On left, unfertilized plot. Note difference in the size of an average head from the two plots, as shown by the two heads on the top of the bushel basket.



*Fertilizer Experiments with Cabbage at Auburn*

| Plot Number | Amount<br>fertilizer per acre | KINDS OF<br>FERTILIZER<br>USED | Yields in pounds per acre |                                       |                   |                                       | Averages       |                                    |
|-------------|-------------------------------|--------------------------------|---------------------------|---------------------------------------|-------------------|---------------------------------------|----------------|------------------------------------|
|             |                               |                                | 1912                      |                                       | 1913              |                                       | Yield per acre | Increase over<br>unfertilized plot |
|             |                               |                                | Yield<br>per acre         | Increase over<br>unfertilized<br>plot | Yield<br>per acre | Increase over<br>unfertilized<br>plot |                |                                    |
| 1           | 656                           | Acid phosphate.....            |                           |                                       |                   |                                       |                |                                    |
|             | 450                           | Sulphate ammonia.....          | 27332                     | 15982                                 | 20068             | 8458                                  | 23700          | 12220                              |
|             | 270                           | Muriate potash.....            |                           |                                       |                   |                                       |                |                                    |
| 2           | 656                           | Acid phosphate.....            |                           |                                       |                   |                                       |                |                                    |
|             | 643                           | Dried blood.....               | 27195                     | 15755                                 | 17361             | 5751                                  | 22233          | 10753                              |
|             | 270                           | Muriate potash.....            |                           |                                       |                   |                                       |                |                                    |
| 3           | 656                           | Acid phosphate.....            |                           |                                       |                   |                                       |                |                                    |
|             | 562                           | Nitrate soda.....              | 31286                     | 19936                                 | 18008             | 6398                                  | 24647          | 13167                              |
|             | 270                           | Muriate potash.....            |                           |                                       |                   |                                       |                |                                    |
| 4           | 494                           | Acid phosphate.....            |                           |                                       |                   |                                       |                |                                    |
|             | 1285                          | Cotton seed meal.....          | 28224                     | 16874                                 | 20534             | 8924                                  | 24379          | 12899                              |
|             | 218                           | Muriate potash.....            |                           |                                       |                   |                                       |                |                                    |
|             | 583                           | Thomas phosphate.....          |                           |                                       |                   |                                       |                |                                    |
| 5           | 562                           | Nitrate soda.....              | 31585                     | 20235                                 | 30141             | 18531                                 | 30803          | 19388                              |
|             | 270                           | Muriate potash.....            |                           |                                       |                   |                                       |                |                                    |
| 6           | 656                           | Acid phosphate.....            | 27850                     | 16500                                 | 16800             | 5190                                  | 22325          | 10841                              |
|             | 643                           | Dried blood.....               |                           |                                       |                   |                                       |                |                                    |
| 7           |                               | No fertilizer—check.....       | 11350                     |                                       | 11610             |                                       | 11480          |                                    |
| 8           | 1285                          | Cotton seed meal.....          | 17248                     | 5898                                  | 14516             | 2906                                  | 15882          | 4402                               |
| 9           | 656                           | Acid phosphate.....            | 11499                     | 149                                   | 12649             | 1039                                  | 12074          | 594                                |
| 10          | 270                           | Muriate potash.....            | 13740                     | 2390                                  | 10634             | 976                                   | 12187          | 707                                |
| 11          | 643                           | Dried blood.....               | 21354                     | 10004                                 | 18668             | 7058                                  | 20011          | 8531                               |
| 12          | 562                           | Nitrate soda.....              | 19414                     | 8064                                  | 18524             | 6914                                  | 18969          | 7489                               |

## CO-OPERATIVE FERTILIZER TEST AT BESSEMER, ALA.

This work was done under the Local Experiment Law and in co operation with the Tennessee Coal and Iron Company

The test was continued for three years. The results are shown in the following table. From the average yields for each kind of fertilizer, we derive the following conclusions regarding the values of the various fertilizer constituents used:

The use of slaked lime, even at the extremely low rate of 207 pounds per acre, in addition to a complete fertilizer, appears to have increased the yield by 2,278 pounds of cabbage per acre. (Plot 5 without lime; Plot 6 with lime.)

An application of 310 pounds of nitrate of soda per acre, in addition to acid phosphate and muriate of potash, gave an increase of 4,311 pounds of cabbage

per acre. (Plot 2 without nitrate of soda; Plot 5 with nitrate of soda.)

The use of 207 pounds of muriate of potash per acre, in addition to acid phosphate and nitrate of soda, gave an increase of 473 pounds of cabbage per acre. (Plot 4 without potash; Plot 5 with potash.)

The use of acid phosphate, at the rate of 620 pounds per acre, in addition to nitrate of soda and muriate of potash, gave an increase of 1,915 pounds of cabbage per acre. (Plot 3 without acid phosphate; Plot 5 with acid phosphate.)

An application of 885 pounds of Thomas phosphate per acre, in addition to cotton seed meal and muriate of potash, resulted in an increase of 1,021 pounds of cabbage per acre. (Plot 9 without Thomas phosphate; Plot 8 with Thomas phosphate.)

In a complete fertilizer, Thomas phosphate gave an increase over acid phosphate of 486 pounds of cabbage per acre. This increase, also noted in experiments carried on at Auburn, may have been partly or entirely due to the lime contained in Thomas phosphate. The beneficial effects of lime are indicated in Plot 6. (Plot 5 with acid phosphate; Plot 7 with Thomas phosphate.)

In whatever combination used, cotton seed meal gave better results than nitrate of soda. This would probably be expected, since all the fertilizers were applied before the plants were set. Nitrate of soda is most effective when used as a top-dressing. (a) Used with muriate of potash only, cotton seed meal gave an increase over nitrate of soda, of 3,156 pounds of cabbage per acre. (Plot 3 with nitrate of soda; Plot 9 with cotton seed meal.) (b) Used with muriate of potash and Thomas phosphate, cotton seed meal gave an increase over nitrate of soda of 1,776 pounds of cabbage per acre. (Plot 7 with nitrate of soda; Plot 8 with cotton seed meal.) (c) Used with acid phosphate only, cotton seed meal gave an increase over nitrate of soda of 441 pounds of cabbage per acre. (Plot 4 with nitrate of soda; Plot 10 with cotton seed meal.)

The fertilizer combination giving the highest yield per acre for the three years was that used on Plot 6; namely, acid phosphate 620 pounds per acre, nitrate of soda 310 pounds per acre, muriate of potash 207



pounds per acre, slaked lime 207 pounds per acre. This plot yielded at the rate of 20,909 pounds of cabbage per acre, an increase of 8,364 pounds per acre over the average of the two unfertilized plots. The fertilizer mixture used on Plot 8, which is a close second, was the following: Thomas phosphate 885 pounds per acre, cotton seed meal 650 pounds per acre and muriate of potash 207 pounds per acre. This plot yielded at the rate of 20,893 pounds of cabbage per acre, an increase of 8,348 pounds per acre over the average of the two unfertilized plots.

Note that in the two unfertilized plots in the several tests that the yields are practically the same, being much lower than any of the plots receiving a complete fertilizer.

Results obtained from both experiments at Auburn and Bessemer show that potash did not increase the yield sufficiently to warrant its use on loam or clay soils. On sandy soils, which are very deficient in potassium, this element must be included in the fertilizers applied.

*Yields for Cabbage in Cooperative Fertilizer Test at Bessemer, Ala.,  
1912, 1913 and 1914.*

| Plot Number | Amount<br>fertilizer per acre | KIND OF<br>FERTILIZER<br>USED           | 1912           |                            | 1913           |                            | 1914           |                            | Average        |                            |
|-------------|-------------------------------|-----------------------------------------|----------------|----------------------------|----------------|----------------------------|----------------|----------------------------|----------------|----------------------------|
|             |                               |                                         | Yield per acre | Increase over unfertilized | Yield per acre | Increase over unfertilized | Yield per acre | Increase over unfertilized | Yield per acre | Increase over unfertilized |
| 1           | Lbs.                          | No fertilizer -----                     | Lbs. 7900      |                            | Lbs. 7181      |                            | Lbs. 21612     |                            | Lbs. 12231     |                            |
| 2           | 620                           | Acid phosphate -----                    | 10804          | 2004                       | 9778           | 1461                       | 22369          | 1851                       | 14320          | 1775                       |
| 3           | 207                           | Muriate of potash -----                 | 11502          | 2702                       | 15768          | 7451                       | 23878          | 3360                       | 16716          | 4171                       |
| 4           | 310                           | Nitrate of soda -----                   | 13883          | 5083                       | 16078          | 7761                       | 23493          | 2975                       | 18158          | 5613                       |
| 5           | 207                           | Muriate of potash -----                 | 13302          | 4502                       | 20195          | 11878                      | 22397          | 1879                       | 18631          | 6086                       |
| 6           | 620                           | Acid phosphate -----                    | 13418          | 4618                       | 25643          | 17326                      | 23667          | 3149                       | 20909          | 8364                       |
| 7           | 310                           | Nitrate of soda -----                   | 15510          | 6710                       | 22654          | 14337                      | 19187          | —1331                      | 19117          | 6572                       |
| 8           | 207                           | Muriate of potash -----                 | 16904          | 8104                       | 21159          | 12842                      | 24616          | 4098                       | 20893          | 8348                       |
| 9           | 885                           | Thomas phosphate -----                  | 15277          | 6477                       | 22261          | 13944                      | 22078          | 1560                       | 19872          | 7327                       |
| 10          | 650                           | Cotton seed meal -----                  | 14057          | 5257                       | 20371          | 12054                      | 21368          | 850                        | 18599          | 6054                       |
| 11          | 207                           | Muriate of potash -----                 | 9700           |                            | 9453           |                            | 19424          |                            | 12859          |                            |
| 11          | 620                           | Acid phosphate -----                    | 8800           |                            | 8317           |                            | 20518          |                            | 12545          |                            |
| 11          | 650                           | Cotton seed meal -----                  |                |                            |                |                            |                |                            |                |                            |
| 11          |                               | Average of two unfertilized plots ----- |                |                            |                |                            |                |                            |                |                            |

### VARIETIES.

The Wakefield and Drumhead types are best suited for general use in the South. The Early Jersey Wakefield is one of the best early varieties, while Extra Early Pilot has matured 3 to 5 days earlier. Charleston Wakefield is the best second-early, both for home use and for market. The Drumhead and Flat Dutch varieties are best for late planting and are heavy yielders. Some of the late varieties do not head. A few varieties are briefly described below:

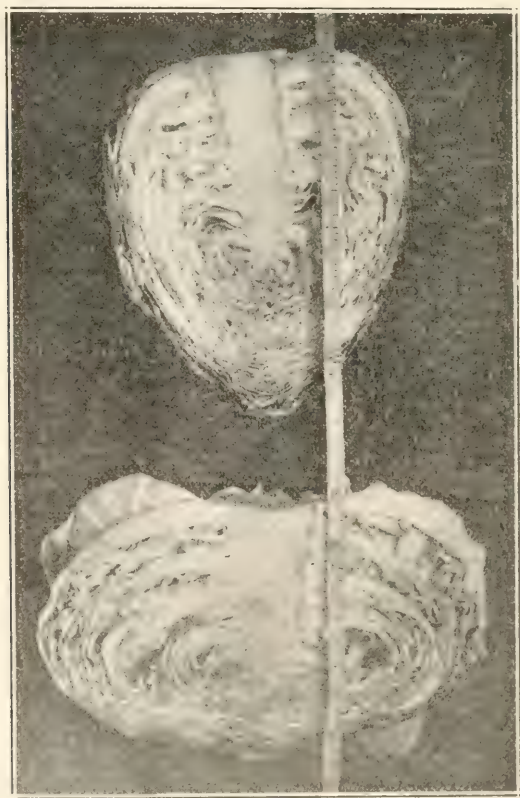
*Extra Early Pilot.*—This variety is the earliest in cultivation; heads are perfectly solid, long, conical shaped; size, small, averaging one to two pounds each;



flavor, good. It will permit much closer planting than the larger varieties, and is highly recommended for home use and for market.

*Early Jersey Wakefield.*—The heads of this variety are extremely solid, are conical in shape, and have few outside leaves. This variety is commonly planted for the earliest, but is several days later than Extra Early Pilot. It is a good grower, and is highly recommended for both home use and market.

*Charleston Wakefield.*—Heads are solid, larger and more roundish than the Early Jersey Wakefield, and a week or ten days later. The crop matures in a short period. One of the best second-early varieties for market and home use.



**Figure 2.**

Upper: Cross section of Charleston Wakefield cabbage.  
Lower: Cross section of Early Drumhead cabbage.

*Early Drumhead.*—This variety makes an excellent succession for the varieties named above, being a few days later than Charleston Wakefield. Heads uniformly compact, large, broad and flattened; hence this variety requires more room than varieties producing smaller heads. It is a good shipper, and is highly recommended for home use and for market.

*Flat Dutch.*—Heads are very large, somewhat depressed in shape, very full and firm. There are numerous outer leaves, large and crimped. It is exceedingly hardy; matures a few days later than Drumhead; recommended for home use.

### *Variety tests at Auburn.*

#### *Yields in Pounds per Acre.*

| <i>Name of Variety</i>             | 1911  | 1912  | 1913  | 1914 | 1915  |
|------------------------------------|-------|-------|-------|------|-------|
| First Crop                         |       |       | 9184  |      |       |
| Early Jersey Wakefield             | 14934 | 11283 |       |      | 11200 |
| Volga                              |       |       | 24890 |      |       |
| Grand Duke                         | 18669 | 13067 |       |      | 19600 |
| Flat Dutch                         | 35842 | 19287 |       |      | 18668 |
| Indian Summer                      | 11896 | 11200 |       |      |       |
| Charleston Wakefield               | 10752 | 13769 | 12445 |      | 24641 |
| Early Drumhead                     | 28076 | 16800 | 16502 |      | 24641 |
| Louisville Drumhead                | 18667 | 14934 |       |      |       |
| Danish Ball Head                   | 12445 | 16801 |       |      |       |
| Red Rock (Failed to head)          |       |       |       |      |       |
| Selected Jersey Wakefield          |       | 11410 |       |      | 12842 |
| Extra Early Pilot                  |       | 10708 |       |      | 6933  |
| Premium Large Drumhead             |       | 17423 | 21057 |      |       |
| Drumhead Savoy                     |       | 11200 |       |      |       |
| Surehead                           |       | 15764 |       |      |       |
| Large Green Glaze (failed to head) |       |       |       |      |       |
| Succession                         |       | 9707  | 14583 |      | 12395 |
| Improved Brunswick                 |       | 13067 |       |      |       |
| All Head Early                     |       |       | 12246 |      |       |
| Victor Flat Dutch                  |       | 12134 |       |      |       |
| Tait's May Queen                   |       | 13515 |       |      |       |
| All Season                         |       | 17174 | 15382 |      | 15576 |
| Early Winnigstadt                  |       | 14306 |       |      |       |

### *Variety tests at Bessemer, Ala.*

#### *Yields in pounds per acre.*

| <i>Name of Variety</i> | 1912   | 1913   | 1914   |
|------------------------|--------|--------|--------|
| Charleston Wakefield   | 14,354 | 21,247 | 17,310 |
| Flat Dutch             | 14,328 | 7,447  | 24,053 |
| Dwarf Flat Dutch       |        | 24,462 |        |
| Jersey Wakefield       | 13,373 |        |        |
| Succession             | 13,347 | 11,155 |        |
| Drumhead               |        |        | 26,321 |
| Large Drumhead         |        | 28,362 |        |
| Early Winnigstadt      |        | 23,270 |        |

## HARVESTING AND MARKETING.

Cabbages are usually harvested as soon as they have attained good marketable size, earliness being an important factor in prices. The stem is cut close up to the head, and the coarse outer leaves removed. Heads that are not sound and firm should never be shipped. The average yield of cabbage in home garden in Alabama is about three tons per acre, but much higher yields than this are frequently made. The yield in the Gulf Coast section of the state is generally from 150 to 200 100-pound crates. Prices vary from fifty cents to \$2.00 per crate; there is little or no profit if the price is less than \$1.00 per crate.

The package most commonly used is the square-ended, rectangular crate, 17x17x30 inches in size, which holds about a barrel or 100 pounds. In packing, care should always be taken to place the stem-end of the cabbage outward, as the stem-end is better able to resist bruising against the sides of the crate. The heads should be packed tightly into the crate, for there will always be considerable shrinkage. It is customary and advisable to mark on the outside of the crate the number of heads contained.

In many cases cabbages are shipped by express, but this is necessarily an expensive method. Growers in a community should co-operate and ship in car-lots, and thus save on the important item of transportation. When shipping in car-lots, close attention must be paid to ventilation, or there may be great loss from heating and decay in transit.

Cabbage is a good cropper. Prices are subject to considerable fluctuation, but quite often nice sums are realized from the crop. The size of the cabbage crop held over in storage in the North should be carefully considered by the southern trucker in planning his acreage of early cabbage, since a large crop stored in the North usually means low prices for the southern crop.

## INSECTS AND DISEASES.

In the production of many crops, clean culture is of great importance in controlling injurious insects and diseases. This includes, in addition to the regular cultivation of any particular crop, the destruction of all nearby weeds and rubbish which may serve either as food or as hiding places. Destroy all crop remnants when the cabbage is harvested. This may be done by



burning or by plowing them under deeply. As a rule, insects which chew or suck juices from the leaves of plants, can be more easily controlled than can fungus diseases, which frequently attack the internal tissues of leaves, stems, or roots.

*The cabbage louse* (*Aphis brassicae*) is frequently injurious to cabbages and related plants. The best remedy is a soap solution, made as follows: Into two gallons of water, shave thinly one pound of ordinary laundry soap. Boil and stir until the soap is completely dissolved, and then add two gallons of cold water. This solution should be thoroughly and forcibly sprayed so as to completely wet the under sides of all leaves of affected plants. "Black Leaf 40", which is a nicotine extract from tobacco, is effective also for plant louse control.

*Cutworms* of several species are very common. These "worms" feed not only on cabbage and other garden plants, but also on grass and weeds; hence the importance of clean culture with the previous crop. Beyond this, the best remedy is poisoned bran-mash, made by thoroughly mixing while dry either one ounce of Paris green with five pounds of wheat bran, or one ounce of white arsenic with ten pounds of wheat bran, and then stirring in a mixture of cheap molasses and water until the "mash" consistency is reached. Fairly satisfactory results may be had by using the mash along the rows at each plant after the cabbage plants have been set. It is better, however, where the ground to be planted was in sod or very grassy during the preceding fall, to take action before planting is done. The soil should be well prepared and thoroughly disked to remove all green food plants that might compete with the poisoned bait, then scatter at evening, green grass, oats or clover dipped in a mixture of one ounce of Paris green in a pailful of water. The baits should be placed at intervals over the bare ground and treatment may be repeated after two or three days and before planting is done. Be careful not to allow chickens to have access to the poisoned mash.

*Cabbage worms*, which cause the large holes in the leaves of cabbage and related plants, can be most effectively controlled by spraying or dusting the plants, prior to heading, with arsenate of lead. If applied in

dust form, one pound of arsenate of lead powder should be thoroughly mixed dry with from ten to twenty pounds of air slaked lime, or dry wood ashes, and dusted thinly on the leaves of affected plants. If a spray is preferred, use one pound of arsenate of lead powder to 50 gallons of water, and apply with spray-pump.

*No danger of poisoning.*—The cabbage heads from within outwards, not by a folding in of the outer leaves as is occasionally supposed. There is no danger of poisoning therefore if the remedies here suggested are used prior to the time the head is half-formed. Most of the cabbage, especially throughout the northern part of the country, is thus treated with arsenical poisons for cabbage worm control. Chemical tests have shown that it would be necessary to eat many hundred pounds of cabbage at one time to convey a poisonous quantity to a human being three weeks after the treatment is given.

*The harlequin cabbage bug*, or "calico-back" (*Murgantia histrionica*), which sucks sap from the leaves of cabbage and other cruciferous plants, cannot be destroyed by the use of arsenical or stomach poisons. They are also very resistant to kerosene emulsion. Clean culture and hand-picking are important measures of control. This insect is more troublesome on the late crops than on early cabbage. Mustard, planted early, or in advance of the later crops, may be used as a trap-crop. The bugs will first congregate on the mustard and deposit quantities of eggs thereon. The mustard may then be sprayed with pure kerosene, or covered with straw and burned.

*Root-knot*:—Roots attacked become knotty at irregular intervals. The trouble is caused by tiny worms (nematodes) which are present in old southern garden soils, especially those which are light and sandy. Since nematodes cannot live on the roots of all kinds of plants, it is possible to partly starve them out by practicing rotation of crops. Some of the plants on which nematodes do not live are corn, oats, Iron and Brabham varieties of cow-peas, peanuts, velvet beans, and crab-grass.

*Club-Root*:—This disease is caused by the presence of a myxomycete, *Plasmodiophora brassicae*, (a low form of plant life) within the cells of the roots, and is

apt to be confused with root knot. In club-root, however, the roots swell into larger finger-like masses or "clubs". The disease is worst in acid or poorly drained soils. The best remedy is slaked lime, applied several weeks before planting at the rate of fifty to seventy-five bushels per acre every few years. Rotation of crops is also important. Avoid plants from soils infested with the disease.

*Black Rot* is a serious bacterial disease, in which the cabbage plant becomes dwarfed or one-sided in growth. A cross-section of the stem of diseased plants will show a dark brown or black ring in the stem just beneath the bark. In severe cases this blackening can usually be traced upward into the cabbage head. In extreme cases, the plant may die. Plants of all ages are attacked. There is no certain method of controlling the disease, but a knowledge of the following facts may enable the grower to prevent it or to hold it partly in check. The disease may be carried by infected seed, by insects, by live stock, or by running water. It might be spread over a large area by throwing a diseased plant on the manure heap instead of burning it.

*Wilt* ("Yellows"), which is very common on cabbage in this state, does not affect any other crop. It is first seen in the lower outer leaves. The whole leaf may turn yellow at the margin or between the veins, later turn brown as if scorched by fire, and finally drop off. Sometimes only half of the leaf is affected while the other half remains green. This is the more usual characteristic of the disease. The lowest leaf is the first to drop off, and is followed by those above in rapid succession until the bare stock remains. Crop rotation should be practiced, to extend over a period of 5 to 8 years.

*"Damping-off"* attacks young seedlings. Under certain conditions damage is often rapid and extensive. It is caused by two or more species of fungi, the spores of which occur in many old garden soils. In the seed-bed where plants are crowded, the soil kept too moist, or the humidity kept too high, with poor circulation of air and insufficient light it is most apt to appear. The young seedlings are attacked at the surface of the soil, the stems are soon girdled and the plants fall over



and die, although the tops appear healthy. Seed should not be sown in soil where "damping-off" has occurred. Do not keep the soil wet by too frequent watering. During the winter or early spring when plants are kept under sash, always water in the morning, rather than in the afternoon. Spraying with weak Bordeaux mixture, or applying road dust, fire-dried sand, slaked lime, or sulfur about the base of the plants will greatly aid in checking the disease.

*Soft-Rot* is a bacterial disease which enters at the root or crown and spreads rapidly throughout the whole plant. The bacteria rarely enter uninjured plants. The greatest damage is done to ripe cabbage, or those in storage. Heavy losses have been sustained where the heads were improperly stored. The disease spreads rapidly over the outer leaves, making the cabbage unsightly and affecting the market value. Avoid fields where the disease has been known to occur. Handle the crop carefully when harvesting, so as to bruise the heads as little as possible. See that the heads are dry before putting them in storage.

#### RELATED CROPS.

Cauliflower, Kohlrabi, and Brussels Sprouts require practically the same treatment as cabbage, as regards soil, time of planting, and culture; except that they are somewhat more sensitive towards both the extreme cold in winter and the heat of summer. Seed should be sown in the cold frame the middle of October, and the young plants hardened off until January, when they should be transplanted into rows in the field. They must be started early enough in the field to avoid the heat of early summer. One of the best varieties of Cauliflower is Early Snowball; of Kohlrabi, White Vienna; of Brussels Sprouts, Long Island.

Collards and Kale are so commonly and so easily grown that no discussion of their culture seems necessary.

**ALABAMA**  
**Agricultural Experiment Station**

OF THE  
**Alabama Polytechnic Institute**

**AUBURN**

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**Boll Weevil in Alabama**

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By  
**W. E. HINDS, Entomologist.**

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\* In co-operation with United States Department of Agriculture



# BOLL WEEVIL IN ALABAMA

By

W. E. Hixes, Entomologist.

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## WEEVIL SPREAD THROUGH ALABAMA.

Since the boll weevil first entered southern Texas in 1892, it has been an increasingly important factor in our annual production of cotton. Its advance northward and eastward, at an average rate of fully 50 miles per year, has continued steadily until it has now crossed our own State, and occurs in more than thirty counties in southwestern Georgia.

*Weevil Entered Alabama in 1910.*— On September 3, 1910, the first specimens of this much dreaded pest were found on the western edge of Mobile County, in Alabama. The weevil advanced so that by the middle of September the line of infestation included about three-fourths of Mobile County. Ten days later, weevils were found in the southern part of Choctaw County also.

*Weevils Entered Six or Seven Alabama Counties in 1910.* The spread of the weevil in 1910 was checked fully a month earlier than usual on account of killing frosts occurring during the latter part of October instead of about the middle of November as is usual in that section. Undoubtedly this prevented a considerable extension of the newly infested area. As it was, the weevils entered five counties in southwestern Alabama and may have occurred also in the extreme corners of Monroe and Escambia. This area (see map, Plate I) is not important so far as cotton production is concerned as it produced less than 15,000 bales of cotton annually upon the average before infestation occurred. The yield in this area for 1915 was about 2,000 bales.

*1911 Movement.* In 1911 the weevils began to move about the middle of August and continued until killing frosts occurred about the middle of November. This advance brought 12 Alabama counties, wholly or partly, within the infested area. The movement was very evidently checked by the formation of immense numbers of squares, following the stripping of the plants by the September generation of cotton worms.

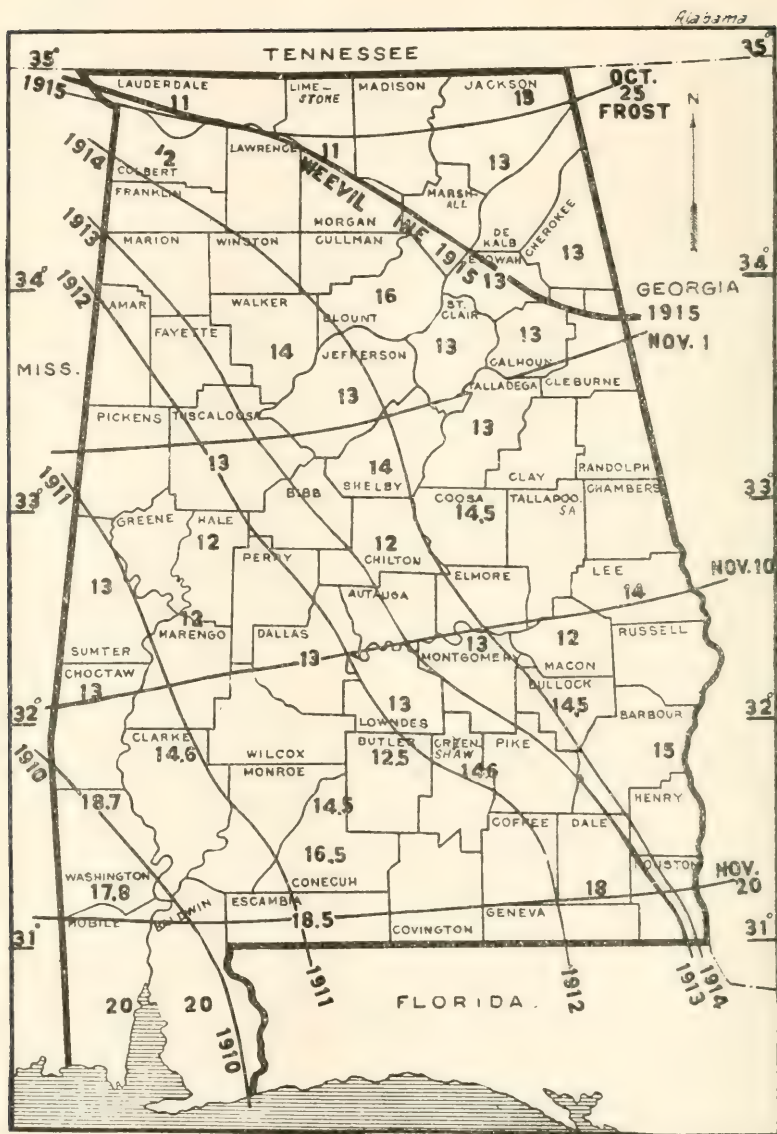


Plate 1.

WEEVIL ADVANCE IN ALABAMA, SUMMER RAINFALL AND AVERAGE DATE OF FIRST KILLING FROST.

Lines running diagonally from Northwest to Southeast show weevil advance from 1910 to 1915.

Figures within county lines show normal total rainfall during June, July and August.

Lines running nearly East and West show average date for first killing frost.

Degrees of latitude are shown on the margins. (Original.)

**1912 Movement.** The actual number of weevils surviving the winter of 1911-12 was very greatly reduced below the usual average survival by three especially important factors: (1) The unusual period of hot, dry weather which continued for about two months in the early summer of 1911. (2) The general stripping of cotton throughout Alabama and other infested states by the cotton leaf worms (*Alabama argillacea*) during the fall of 1911. This stopped the fall multiplication of weevils by destroying or preventing the formation of their only possible breeding places and gave us the finest possible demonstration of the value of a general practice of the early fall destruction of stalks as a method of weevil control (see pp. 47-55). (3) By the unusually severe winter weather in 1911-12. The weevils reached Coffee and Geneva counties this season, making an advance of about 75 miles in south-central Alabama.

**1913 Movement.** Extremely early frosts occurred on the mornings of October 20 and 21, almost a month earlier than the average date for first killing frosts in this State, and extended along practically the entire line of weevil advance. Some sheltered localities escaped killing temperatures, but as a general rule the advance was checked about that time. Largely on account of the short season for their spread, the weevil advance averaged only between 20 and 25 miles.

**1914 Movement.** Again, unusually early killing frosts put an early stop to the advance of the weevil. In the southern part of Alabama, the weevils were very effectively controlled during the early summer by an unusual period of hot, dry weather. In many localities where the weevils had been for two years, practically none were seen until after the middle of July when more rain fell. Thereafter weevils multiplied so rapidly that in spite of the early control, little cotton was made after the middle of August. On account of this unusual combination of summer climatic conditions, cotton in the southern third of the State put on an extremely heavy top growth through August, September and October. This furnished the weevils developing after July, with an abundance of uninfested squares and bolls right in the fields where they developed and there was, consequently, no necessity for such widespread dissemination as usually occurs after August 15. These facts may fully explain the failure



of the weevils to advance in southeastern Alabama as they would usually have done.

*1915 Movement Greatest Ever Known.* Killing frost occurring generally throughout North Alabama about November 15 put a stop to further advance of the boll weevil in that section for 1915. This is about three weeks later than the average date for killing frost in the Tennessee Valley and gave the weevils opportunity to spread somewhat farther than they could have done in an average season.

The advance of the weevil for 1915 covered more new territory than in any season since it entered Texas in 1892. In the fall of 1914 the weevil line passed through Houston County, Alabama, within a few miles of the Chattahoochee Valley. The infestation of Houston County, however, occurred so late in the season of 1914 that the weevils failed to maintain themselves beyond the eastern part of Geneva County, where they were found scatteringly in the early summer of 1915.

Early in September, 1915, traces of boll weevil work were discovered in the vicinity of Thomasville, Georgia, which was beyond the distance that the weevil would normally have reached by the end of the season. Immediate investigations in Georgia and Alabama revealed the fact that a remarkable movement of the weevil had occurred, apparently between the 20 and 23 of August. This movement had carried the weevils for more than 140 miles in an eastwardly and northeastwardly direction beyond the 1914 line in Alabama. Throughout this newly infested territory, the infestation evidently began at practically the same date, as weevil stages, eggs and grubs, found 100 miles away were as old as those found only a short distance beyond the 1914 line. A similarly great advance was made by the weevils into western Texas and central Oklahoma where more than 25 counties were invaded for the first time.

*Spread By Winds.*—An examination of the Weather Bureau records in Alabama revealed the probable explanation for this unusual movement in this eastern section. It is found in a heavy wind from the West and Southwest which occurred on August 20, following the severe storm at Galveston, Texas. Weevils do not take flight in a heavy wind but if caught by strong wind currents high above the surface they may be carried for long distances and the greatest advance

movements appear to have been due to this wind factor.

*Alabama Nearly All Infested.* Only five counties in northeastern Alabama now lie outside of the weevil infested area and they are quite certain to become infested in the fall of 1916. The weevils are now in southwestern Tennessee; Mississippi is all infested and they have crossed the Tennessee Valley in this State. The complete infestation of Alabama cotton fields must be expected by the fall of 1917 at latest.

*Quarantine Regulations Nearly Past.* As the weevil advances, the quarantine line against it must move forward accordingly. No restrictions whatever apply now in Alabama to shipments of cotton seed or other products, household goods, etc., within the weevil infested area. All boll weevil quarantine regulations will therefore soon be a thing of the past so far as any shipments destined to any Alabama points are concerned but the regulations of other states must still be observed to continue the fullest possible protection for their uninfested territory.

*The Fight Must Be Made Now.* All cotton planters within this infested area in Alabama should plan to take up the fight against the boll weevil immediately, even if they have not yet been forced to do so by severe weevil injury. Avoid the loss sure to follow if cotton culture be continued in the usual way. Cotton can still be grown profitably and yields may be even increased, where the summer rainfall is less than 14 inches, by the immediate adoption of the improved methods which are described in this bulletin.

*Damage Largely Preventable.* The advent of the weevil is a fact of the utmost importance to the cotton planters of Alabama. Only by immediately adopting and putting into practice part or all of the methods which have been found most effective in controlling the weevil in Texas, Louisiana, Mississippi and other states can the planters of Alabama avoid passing through the same experience of loss as planters have suffered in previously infested territory. These methods have been thoroughly tried and have proven practical and effective. It is the object of this and other publications of the Alabama Experiment Station to show exactly what methods should be adopted and how the damage done by the weevil to cotton may be reduced as much as is possible. The following para-

graphs briefly describe the different stages of the weevil as they are found in cotton, and outline the life history so that the reason for the effectiveness of many of the practices advised may be evident to the intelligent reader. By following these suggestions closely the damage which the boll weevil will necessarily inflict may be reduced to a small part of what it will do if its presence is ignored and old methods of cotton production are continued.

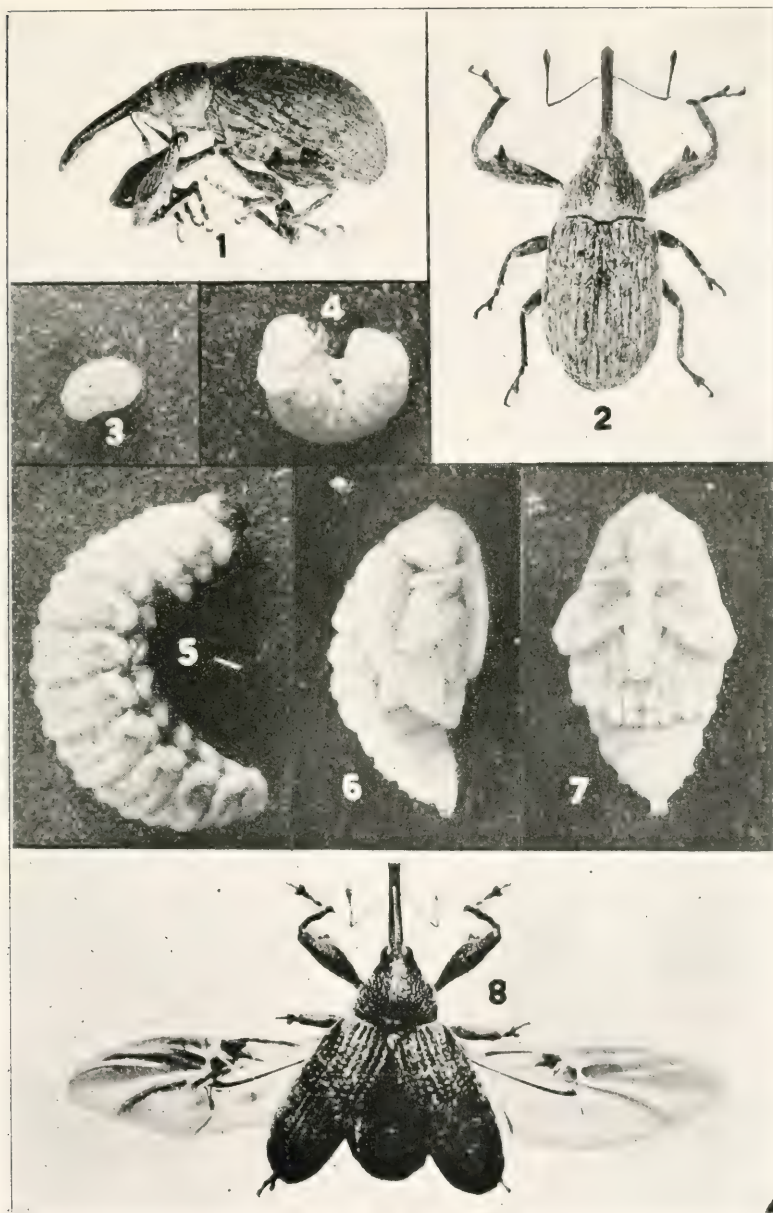
## STAGES AND WORK OF THE BOLL WEEVIL.

*The Boll Weevil Attacks Cotton Only.* The boll weevil is a beetle belonging to a large group all of which have a part of the head in front of the eyes greatly extended to form a long, slender snout. There are many hundreds of species of these insects, all of which are commonly called "weevils," but the Mexican cotton boll weevil is the only one attacking cotton in this country. Another species attacks cotton squares in Peru, South America.

*Other Weevils Mistaken For Boll Weevil.* The weevils so commonly found during the fall and winter in the stems and roots of cocklebur, ragweed, etc., are different species entirely. They are often mistaken for the boll weevil. (See Alabama Extension Leaflet No. 10.) The boll weevil breeds in cotton squares and bolls and nowhere else. The species in cocklebur is known as the cocklebur weevil or "transverse Baris" and that in ragweed is the "ragweed weevil." These weevils do not attack cotton and the boll weevil never occurs in these weeds. In the spring a species of weevil which breeds in cowpea pods and is known therefore as the "cowpea pod weevil" is found quite commonly upon young cotton where it does some damage by feeding on the buds and tender leaf stems as does the boll weevil. The cowpea pod weevil is about the size of the boll weevil but is solid black in color and the surface of its body is evenly covered with small pits or dents which give it a very different appearance. This cowpea weevil does not breed in cotton. It is simply feeding there while waiting for cowpeas to develop and then leaves the cotton for the cowpea fields where it occurs during the balance of the season.

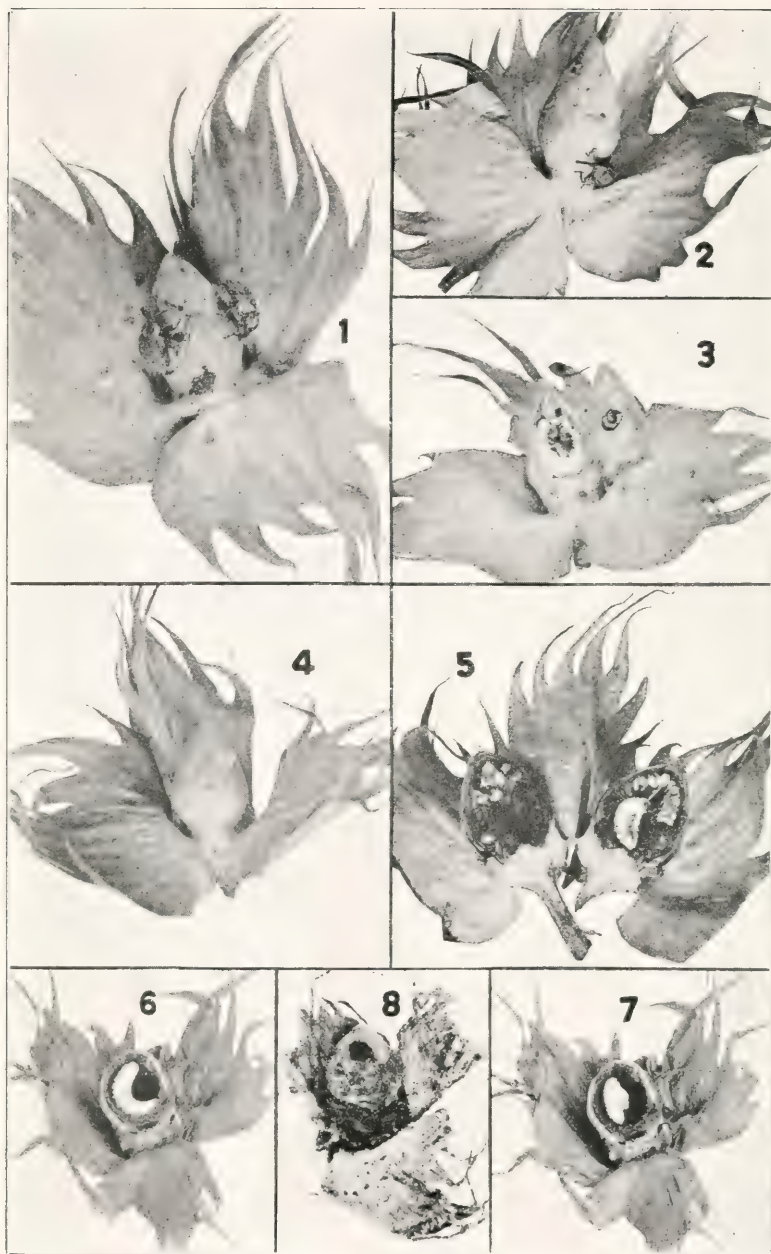
*Four Stages: 1. Egg.*—Like all other beetles the boll weevil has four distinct stages in the development of each individual. The first of these is the egg, which





### BOLL WEEVIL STAGES.

Figure 1, Adult weevil, side view; fig. 2, adult, viewed from above; fig. 3, egg of weevil; fig. 4, grub at entrance to second stage after shedding first skin, about three days old; fig. 5, grub fully grown, about ten days from egg; fig. 6, transformation or pupal stage, side view, snout, legs and wings forming; fig. 7, pupal stage, front view of fig. 6; fig. 8, adult, wings spread. Figs. 1, 2, 5, 6, 7 and 8 enlarged about ten diameters; figs. 3 and 4, enlarged about twenty diameters. (Original.)



#### WEEVIL WORK ON SQUARES.

Figure 1, Adults feeding, male head upward, female head downward; fig. 2, orange-colored masses of excrement, work of young weevil; figure 3, interior of feeding puncture; fig. 4, egg puncture in usual position; fig. 5, grub half-grown at falling of squares; fig. 6; full-grown grub; fig 7, transformation from grub to beetle occurs within squares; fig. 8, emergence hole made by weevil escaping from square. All natural size. (Original.)

is only about 1-30 of an inch long, white and very delicate. Plate II, figure 3. Eggs are always deposited in cavities which the female eats in the squares or bolls and nowhere else upon the cotton plant, and never in any other common plant.

2. *Grub*.—From the egg there hatches in a few days a white, legless grub or worm which does not at all resemble the beetle which it may finally become. The grub of the boll weevil, (Plate III, figures 5 and 6 and Plate IV, figures 4, 5, 6, 7, 8.) resembles very closely the "worms" found in peaches and plums, but those are the grubs of another species of weevil, known as the plum curculio. The boll weevil grub grows steadily from a length of about 1-25 of an inch when it hatches until it becomes fully grown and measures 1-5 to 2-5 of an inch in length, Plate II, figures 4 and 5. The largest grubs are produced in large bolls, Plate IV, figures 6 and 8.

3. *The Pupa*.—In order to attain the beetle form the grub must pass through an intermediate "transformation stage", which is known as the "pupa". In this stage no food is taken, and there is a complete change of the appearance and of structure. The grub sheds its skin and instead of the legless, wingless, snoutless "worm", the pupa appears with all of these organs forming in sheaths closely applied to the body, Plate II, figures 6 and 7. In this stage the insect is very delicate, and perfectly helpless. It, as well as the egg and grub stages, is passed wholly within the interior of the square or boll, Plate III, figure 7; Plate IV, figure 9. These three constitute the immature stages in the life of the weevil, but are as characteristic of the species as is the adult form.

4. *Adult*. After a few days the pupa sheds its skin and becomes the fully formed adult weevil, Plate II, figures 1 and 2, having the legs and snout free and usable, as are also the wings. The wings when not in use are folded back under, protected and hidden by, the hard wing-covers, which meet in a straight line over the middle of the back of the beetle. For a few days the adult also remains protected within the square or boll while it becomes hardened and more able to care for itself. It then cuts a circular hole just the size of its body in the wall of its cell in the square, Plate III, figure 8, and through this opening makes its escape into the outer world, where from that time on



it leads a free and active life. Weevils escape from small bolls as they do from squares, Plate IV, figure 5, but in large bolls they wait for the boll to mature and crack open before they mature and then have only to cut their way through the wall of the cell in which they have transformed, Plate IV, figure 6.

The adult beetle, found on cotton only, is about 1-4 inch long, including the slightly curved snout which is one-half as long as the rest of the weevil's body. The color is dark brown, ashy-gray, or yellowish brown.

*Signs of Injury.*—Among the most conspicuous external signs of boll weevil presence and injury are the following: the occurrence of open cavities 1-25 to 1-30 inch in diameter and reaching down to larger excavations among the pollen sacs, Plate III, figure 3 and Plate IV, figures 1 and 2; the presence of "warts" marking the egg punctures of the weevil; the occurrence of the orange-colored excrement of the beetles on the buds, Plate III, figure 2; the abundant shedding of squares and the consequent scarcity of blooms without accompanying temperature, rainfall or cultural conditions to cause the shedding.

## HOW WEEVILS SPREAD, MULTIPLY AND PASS THE WINTER.

*Weevils Fly.*—The full-grown weevils fly, especially during the period from about August 15 to November 15, and their spread into new territory is accomplished almost entirely in this way. The wings, when not in use, are folded under, and closely covered and protected by the hard wing covers that meet in a straight line along the middle of the back of the weevil. As they appear when extended in flight, the wings are shown in Plate II, figure 8.

*Multiply in Top Growth.* When female weevils reach new, uninfested territory, they feed for a short time and then begin to deposit eggs at the rate of from 6 to 10 per day, in such squares and small bolls as they can find. The egg puncture, Plate III, figure 4, is sealed up air-tight, after the egg is deposited. Each female may lay several hundred eggs and in the course of three or four weeks a new generation will be produced in this field. These weevils may continue the process so that before frost kills the plants, a large number of weevils will have been developed from the few weevils which flew into new territory. To prevent this breed-

ing, and to control the weevils most effectively and economically, we strongly recommend the practices of producing an early maturing crop of cotton, harvesting as soon as the cotton can be picked out and then immediately turning under the stalks.

*Weevils Breed in Cotton Until Frost Kills it.* Weevils are absolutely dependent upon cotton for feeding and breeding. As a rule, the number of weevils in the field is considerably reduced during the period while cotton is opening because the number of available breeding places is then reduced as squares become scarce and most bolls are too large for the weevils to infest them. After the crop is matured, if favorable rains occur, there is usually a considerable growth of late squares with blooms and many small bolls formed. This condition is remarkably favorable for the development of weevils, and the number of weevils increases very rapidly until frost destroys the cotton.

*Establishes Species in New Territory.* Migrated weevils, which have flown many miles into new territory, are likely to find just this late growth of squares in which they may reproduce and thus establish the species in the new territory. It is possible for two or three generations to be thus produced before frost. The danger is that planters may not realize the presence of the weevils, as the fields are usually neglected after the cotton is picked out, and thus the conditions most favorable for the weevils are left without a single effort being made to change or remove them. Naturally not as many weevils are likely to be produced during the first season in the new territory as may be found during the fall in older infested fields, but the danger to the crop of the following year may be nearly as great under certain conditions.

*Many Thousands of Weevils May Occur on Each Acre of Cotton.* In old infested fields, it is by no means uncommon to find from one to four or five weevils for each plant growing in the field. This means that from five to twenty-five thousand weevils per acre may be found at the time of the first frost. More than 50,000 weevils per acre have been found in the late fall in some cases where careful collections of weevils were made.

*Late Developed Weevils Most Likely to Survive.*—It is a well established fact that the weevils developing and becoming adult late in the fall are those which

are most likely to survive the winter. They have not exhausted their vitality by long flights or by any considerable reproductive activity, as have older weevils. It becomes doubly important therefore that the development of weevils late in the fall should be prevented as much as is possible.

*Hibernate in Adult Stage.*—As with most insects, the winter season is passed quietly and without feeding by the full-grown or adult weevils. These seek shelter from the cold in or under any kind of rubbish near where they are feeding when the first frosts occur. After this time they can live for months without any food. This dormant, winter condition of the insect is spoken of as hibernation.

*Hibernation Usually Begins At First Killing Frost.*—As cool weather approaches in the fall, weevils become less active and some may seek winter shelter even before frost occurs. Most of them, however, continue to feed until green cotton is largely destroyed. The occurrence of the first killing frost is a signal for the great majority of weevils to seek shelter for the winter. This we call entering hibernation. If the freeze is severe enough to completely destroy squares and bolls, the immature stages may be killed at once or some may complete their development and emerge but practically all of these will die before spring as they have never fed.

*Hibernation Shelter.*—Weevils pass the winter as adults hiding in or under any kind of trash which may be found in or around the cotton field. The old hulls on standing cotton stalks are among the most common places of shelter. Weevils also crawl under leaves and into dense bunches of grass on the ground. Very weedy or bushy places are favorable for weevil hibernation. Ditch banks, terraces, fence rows, timber fringes, stumps in the field, etc., are therefore important places to be cleaned up and cared for where the weevil occurs as this reduces the chances of weevils living through the winter.

*Spanish Moss Especially Favorable.*—Wherever this long gray moss occurs abundantly near cotton fields it is certain to furnish extremely favorable winter shelter for many weevils. Not only is the percentage of survival large in this moss but the weevils emerge from it unusually late because it keeps them cool in spite of high air temperature outside. This moss grows



only where the winters are mild and the summer atmosphere is exceptionally moist or humid. As a result of all of these influences the presence of Spanish moss has come to be regarded as a very certain indication that heavy weevil damage will occur in that vicinity. In fact, in such sections cotton culture has usually been found so uncertain that it has been largely given up in favor of more certain and profitable crops.

*Hibernate Principally Within Cotton Fields.* Under ordinary conditions, few weevils fly to any considerable distance from the cotton fields in search of winter quarters. They have no power of purposely selecting exceptionally favorable shelter conditions. It is well known, however, that during warm days following frosty nights, weevils having little shelter may be again somewhat active and again enter shelter, so that in time the weevils gradually secure the most favorable shelter available. The large majority of weevils find winter quarters in or near the field in which they were feeding when frost occurred.

*Standing Stalks Give Most Favorable Shelter For Weevils.* Innumerable experiments have shown that the most favorable conditions for successful hibernation are found in fields in which cotton stalks, with grass, weeds, fallen leaves, etc., are left undisturbed until nearly time to plant the following spring. Under these conditions, the maximum number of weevils will survive, and unfortunately this is the most common practice throughout the infested area.

*Under Exceptionally Favorable Conditions Over 40 per cent. of the Fall Weevils May Survive.*—A large number of carefully planned and executed experiments has been made to determine the effect of the destruction of green cotton at varying dates in the fall, and the effect of various classes of shelter, upon the survival of weevils. It has been found that the range in survival is sometimes as low as a fraction of one per cent. when conditions are unfavorable, and again as high as between 40 and 45 per cent. where exceptionally favorable conditions and seasons have occurred. It is needless to say that there is very little prospect for successful cotton culture under the latter condition.

*Average Survival About 3 per cent.* A close study of the weevil in Texas and Louisiana during a number of seasons and in widely separated localities indicated

that there the average survival was about 3 per cent. of the number of adult weevils present in the field at the time that killing frost occurred. While climatic conditions in Alabama may vary somewhat from those under which this result was found, the winter conditions are no more severe.

*Weevils Leave Winter Quarters Gradually in Spring.*

Wherever weevils become established in the fall some will come out of winter quarters the next spring and be ready to attack cotton as soon as it breaks ground, but the very last of the weevils leaving winter quarters may not emerge until even as late as the first of July. The period during which weevils are emerging from their winter shelter extends beyond three months. They are therefore ready to attack cotton at any time and can live upon the tender stems for as long as is necessary before squares begin to form.

*Breeding Begins in Squares.*—As soon as squares appear the weevils concentrate their attacks upon them, feeding and laying their eggs therein. By the middle of August it is likely that the weevils will be so abundant, if nothing has been done to control them, that no further cotton will be set. The period from the setting of squares to the formation of a goodly number of half-grown to three-fourths grown bolls should be made as short as possible and upon the abundance of fruit set during this period depends the cotton crop in weevil infested fields.

*Migration Occurs During Fall.* From the middle of August until frost checks their movement, many weevils will fly in search of uninfested squares. This flight constitutes the fall spread of the insect. The spread across Alabama from 1910 to 1915 has been quite fully described in the first portion of this bulletin.

## FIGHTING THE BOLL WEEVIL.

*Infestation Permanent.* The Mexican cotton boll weevil must be reckoned with in the production of all future cotton crops within the infested area. It is not a passing pest as many may expect it to be. It will continue to be a factor in cotton production in Alabama so long as cotton shall continue to be grown.

*Cotton Growers Must Reckon With The Weevil.*—Observations as to the effect of the weevil in newly infested territory in reducing cotton production shows

that in sections where the attempt was made to continue cotton raising in the old way, the yield has often been reduced anywhere up to 90 per cent. of the normal crop during the first few years of the weevil's presence. In the sections near the Gulf Coast having 18 or more inches of rainfall in June, July and August, cotton has been practically abandoned. Gradually the methods of raising cotton became adjusted to the necessities of the case. In sections having less summer rainfall, other crops besides cotton are grown increasingly, and the cotton crop has in some sections regained its normal size, especially where the June to August rainfall is less than 12 inches. The last condition of the cotton grower is better than the first, but the path of progress has led through several years of loss and suffering. Through the accumulated knowledge and experience of experts who have been fighting the weevil, and the demonstrations of many thousands of planters, we now know that through much of the infested area the weevil can be controlled and cotton culture continued even more successfully than has been usual in the past. A study of the effect of the weevil upon cotton production may be found in Alabama Experiment Station Bulletin No. 178.

*Not A Hopeless Fight.* But to continue growing cotton successfully, several improvements in our agricultural practice are imperative. Some of the steps in a reliable system of fighting the weevil successfully will be briefly outlined in this bulletin. This outline cannot even mention many points which might be profitably followed, but is intended to show only the principles and some of the special practices which have proven effective in other sections and which will in time become generally adopted here.

*Begin Fight Now.*—Shall we not begin this fight at once, rather than first lose a large part of two or three crops and then be forced to adopt these ideas? Do not think that the weevils will fail to find your cotton fields or that they will do any less damage therein than they have done elsewhere under similar conditions of soil, climate, etc., unless you make a better fight against them than has been made generally elsewhere.

*Zones of Injury.* It is true that weevil injury varies in different sections but it is quite fairly constant under the same set of environmental and cultural conditions. Study your own situation and compare it with other

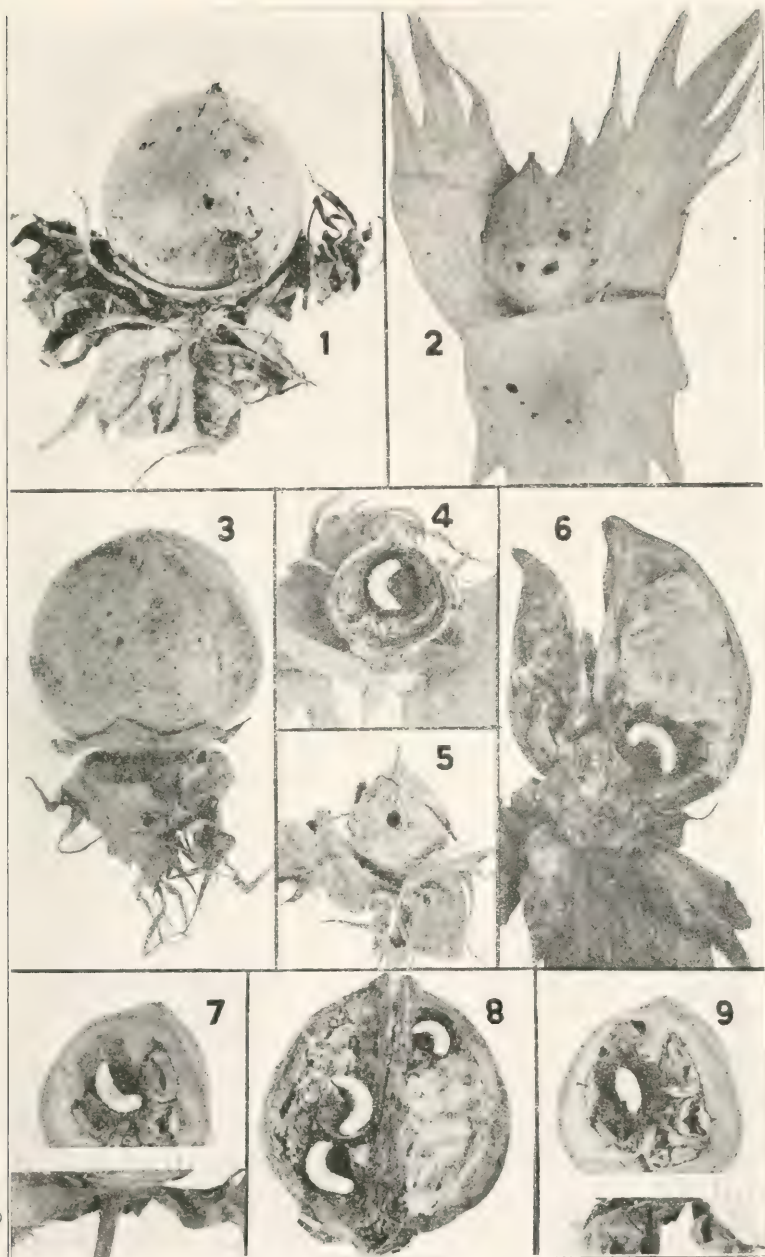


similar sections where the weevil has been for three or more years if you would get a fair idea of the injury the weevil is likely to do in your section. See Plate I. This matter is discussed in Bulletin No. 178.

*Summer Rainfall Most Important Factor.*—It has been found that boll weevil injury varies quite directly with the amount of rainfall during the three months of June, July and August, as this is the period when cotton is putting on most of the crop. This is the period covered in all cases where rainfall is referred to in the following paragraphs. With a rainfall of more than 18 inches in this period cotton is usually a failure, while with less than 8 inches in these three months, as is the case in western Texas, the weevil is likely to be a negligible factor and may not be able to survive through the season. The average rainfall through the Cotton Belt for these months is 14 inches. In Alabama this 14-inch line passes through Randolph, Chambers, Lee, Russell, Bullock, Montgomery, Crenshaw, Butler, Conecuh, Monroe, Wilcox, Marengo, and Choctaw Counties. On Plate I, the normal rainfall is shown by the figures in each county at approximately the location of the weather recording station.

*Southern Third of Alabama Will Lose Half or More of Cotton Crop.* Along this 14-inch line in older infested territory the average decrease in cotton yield, including weevil injury and reduction in acreage, has been fifty per cent. Between the 14-inch line and the Gulf Coast, where the rainfall is from 18 to 20 inches, cotton is bound to be a very uncertain crop, making a fair yield in very dry seasons and liable to be a failure in wet seasons. In this portion of the State the largest degree of change must be made in the whole farming and economic system on account of the weevil. Here we must have the largest reduction in cotton acreage and a proportionate increase in other crops, pastures and livestock.

*Reducing Cotton Acreage.*—No man should attempt to raise more acres of cotton per plow than he is reasonably certain of being able to give all of the extra care that will be demanded under weevil conditions, even if there should be a little more than the average rainfall that is due in his section. Therefore, in the counties along the line of Washington to Henry County and southward, with 16 to 18 inches of summer rain, it is not wise or safe for the average man to try to raise more than 5 acres of cotton per plow. Between this line and a line passing about East and West through



## WEEVIL WORK ON BOLLS.

Figure 1, Weevil feeding on three-fourths grown boll; fig. 2, feeding punctures in small boll; fig. 3, two egg punctures in one lock of large boll; fig. 4, grub full-grown in small boll; fig. 5, emergence hole of weevil from small boll; fig. 6, grub full-grown in large boll; fig. 7, grub destroying two locks; fig. 8, several weevils may develop in a boll; fig. 9, pupal or transformation stage in a boll. All figures about natural size. (Original.)



TYPE OF COTTON PLANT FOR WEEVIL AREA.

Fourteen weeks after planting, height of plant 30 inches, spread 30 inches. Evenly and abundantly branched and very short jointed. When photographed had 35 bolls set, several blooms and over 50 squares. Bolls of good size and shape; four and five locked.



Montgomery, having about 14 inches, we would advise not more than 6 or 7 acres per plow where the weevil has been present for more than one year. From Montgomery northward the acreage may be increased at the rate of about one (1) acre per plow for each 35 miles northward, thus allowing about 10 acres per plow in the latitude of Birmingham and 12 acres per plow in the Tennessee Valley.

Only where a man has cleaned up his cotton stalks early the preceding fall or has available an unusually large number of children to help with the summer weevil fight should the foregoing estimates as to safe acreage be materially increased.

*Raise a Variety of Crops: Diversify.*—The weevils can live only on cotton, but neither the farmer nor his livestock can do this. Our monopoly of cotton raising and the assurance of some crop even with the most shiftless of methods, have been among the greatest curses of our southern agriculture. The effect has been particularly bad during the past fifty years. We cannot continue a "one crop" (cotton) system with the boll weevil present. We can and must raise a variety of crops. This is diversification. Plant especially such crops as can provide food supplies for man and beast on the farm. Stop having to buy and pay big profits to others for the food that you can as well raise at home. Diversification makes it more possible also to use cover crops to build up the soil and make it more productive without depending solely on expensive commercial fertilizers. In no section of the United States can a greater variety of crops be grown than here in Alabama, and we have the added advantage over most of the country of being able to secure from two to four crops each year on the same field.

*Plan Your Diversification.*—Under these conditions the thoughtful farmer is certain to plan to raise a variety of crops. First, he will plan to raise at home as much as possible of the food supply that may be needed by the family and livestock during the year. Second, he will plan to have some surplus in crops and livestock that can be marketed and, where possible, bring in some cash at intervals during the season so that there will be no need to go into debt. Third, he will plan for such a variety and sequence of crops as will most nearly keep all of his cultivated land occupied and growing something

during every month of the year. Fourth, he will plan for crops that can be handled satisfactorily with the work stock and tools available or obtainable and, fifth, which will tend to conserve and improve the fertility and productiveness of the soil upon which his future prosperity must depend.

*Rotate Crops.*—According to these plans and purposes of the progressive farmer, and also in order to minimize injury by numerous insect pests (including the boll weevil especially) and fungus diseases, there will be a wise rotation of crops. Cotton will no longer be permitted to follow cotton every year as has been the common practice for the past fifty years.

*Increase Humus and Nitrogen.*—The vegetable matter in the soil (humus) can be increased and fertility can be improved especially by using such crops as clovers (especially bur or crimson) cowpeas, beans, velvet beans, vetches, etc. The growth of weeds may be prevented and the injury due to both fungus diseases like the boll rot and insect pests such as the boll weevil may be largely reduced by the practice of rotation.

*Prepare Soil More Deeply and Thoroughly Before Planting.*—The nature and extent of preparation to be given the soil before planting and the cultivation to be given the crop while it is growing become exceedingly important questions in producing profitable crops and especially early maturity in cotton. It is needless to say that the average cotton field is not "worked," it is barely "scratched." The results of innumerable experiments and the practical experience of all of the most successful planters prove that deeper plowing with more thorough working of the soil before planting is one of the first principles in any more successful system of agriculture. Deep plowing should generally come in the fall but thorough spring preparation is also essential to best results with most crops.

*Cotton Crop Must Be Made Rapidly.*—No principle has been more clearly established than this. Successful cotton crops in weevil infested territory must be made rapidly. The multiplication of the weevil is so rapid that after the third generation becomes adults there is little chance for more bolls to be set. The presence of the weevils absolutely prevents any "top crop," and usually makes the raising of "late cotton" practically an impossibility.

*Early Planting Alone is Not Enough.*—More things are involved in making a good crop of cotton early than merely early planting of the seed. That alone is not enough to secure success. It is not so much a question of any date on the calendar or of "planting extra early," as it is of reducing as much as possible the time between the first formation of squares and the development of an abundance of bolls to a size at which they are practically resistant to weevil attack. With most varieties of cotton weevils cannot puncture and successfully deposit eggs in bolls that are more than two-thirds grown. The thicker the hull the earlier in its growth does it become immune to attack.

*Varieties of Cotton For Weevil Conditions.* First of all we may emphasize the fact that there is no "one best variety" of cotton for all conditions. There are many good varieties and from this list the cotton planter should select such as best suit his conditions. The real basis finally is that of actual experience, of the demonstrated ability of a variety to produce the best yields under the best agricultural conditions that the farmer is able to maintain.

*Wilt Resistance of First Importance in Some Sections.* Wherever cotton wilt or black root occurs commonly the quality of "wilt resistance" must be the first considered in selecting cotton seed for wilt territory. Several very good varieties have been developed by individuals and by state and government agents. Write the Director, Alabama Experiment Station, Auburn, for information about these.

On soils giving naturally a small plant, it does better to use varieties of cotton which are naturally of larger than average growth. On such soils these varieties may be hastened in maturity and will not produce such heavy foliage as to favor weevil multiplication as they are likely to do on rich soils. Among these varieties are such as Triumph, Cook's Improved, Wannamaker's Cleveland, and others of similar type.

*For Rich Lands.*—Here we would choose some of the smaller growing, more prolific types of cotton which will not produce too large a weed with its dense shade, while the size of the bolls is somewhat increased. There are many of these so-called "early maturing," prolific varieties from which choice may be made. King's Improved and many selections from original King stock such as Simpkins, Broadwell, etc. etc.



*Characters to Avoid in Cotton.*—Avoid both extremes in the matter of branching of the plant. On the one hand, the “limbless” or “cluster” varieties hold all infested squares and do not permit them to fall to the ground where the weevil stages might be destroyed in large numbers by the heat of the sun. The small amount of shade produced is therefore of no advantage. This retention of infested squares favors a larger percentage of development among weevil stages within and the close grouping of squares facilitates more rapid and abundant infestation by the weevils which do not have to travel far from one square to another. On the other hand, the long-jointed, rank-growing varieties produce both a maximum of shade which keeps the sun from exerting its possible control and they also set a minimum of fruit in the period required to produce three generations of weevils. Therefore, the weevils can often destroy all squares on such cotton as fast as they are formed. The result is liable to be a complete failure in the crop with such rank, late-growing varieties. A good type of plant is shown in Plate V.

*Plant as Early as Soil and Air Conditions Are Favorable.*—It is a well known fact that moderately early planted cotton commonly yields better than that planted late. Extremely early planting is hardly desirable or advisable. The object is to have the plant grow off rapidly and steadily, so that the fruiting may be abundant and the period from squaring to the real making of the crop may be as brief as possible. Plant then as early as soil and air conditions become favorable for the rapid and continuous growth of the cotton. The date for this will vary in different seasons and in different sections of the State.

*Uniform Date For Planting Desirable.*—It is an advantage to have all cotton in a locality reach the squaring condition at approximately the same date. Weevils cannot begin to reproduce until squares form. If one field in a locality forms squares a month earlier than does another nearby field it will produce a generation of weevils which may spread to the later field and injure it very seriously before it can set its crop. Thus while the earlier field may produce a fair yield, the later field may produce nothing. A difference of three weeks in date of planting in adjoining fields has been seen occasionally to make all the difference be-

tween a yield of two-thirds of a bale per acre and an absolute failure. Where all fields in the locality develop together the weevil finds no such advantage for its multiplication and must therefore do less injury.

*Late Planting Inadvisable.*—Do not be misled by newspaper "letters" advising late planting to "starve out" the over-wintered weevils. The writers of such letters are usually sincere men who have an idea that this plan should be effective. They do not happen to know what has been found repeatedly to be the fact: That while a few weevils will come from their winter quarters and be looking for food even before the earliest planted cotton will break ground, many will not stir to seek food before the latter part of June or even the first of July. Extremely late planting, with the idea of starving out the over-wintered weevils is therefore doomed to failure and should never be attempted. This has been tested many times and has always resulted in loss.

*Cultivate Often And About one and one-half Inches Deep.*—Cultivation of the crop should be shallow and frequent. Its first object is to retain moisture and to keep the ground in a favorable condition for the growth of the plants. The destruction of grass and weeds is accomplished incidentally. The surface of the ground should be stirred at least every week during the growing season to a depth of about 1 1-2 inches. Where the weevil is found the crop should not be "laid by" as early as usual, but cultivation continued two or three weeks longer if possible to get through the row without much breaking of the plants. This may well be continued until cotton begins to open.

*Use Chain Drag or Cultivator.*—In Press Bulletin No. 78 of the Alabama Experiment Station, will be found an illustration and description of a very simple home-made implement which can often be utilized to excellent advantage not only in giving an ideal type of shallow, surface cultivation, but also in checking the multiplication of the weevils during periods of hot, dry weather. The arrangement of the chains is such that they draw the fallen infested squares from under the shade of the plant to the middle where the heat of the sun may destroy the weevil stages in them.

*Pick Weevils When Squaring Begins.*—Beside the cultural practices which have been mentioned there are two special steps that are necessary where weevils are

abundant, and especially where the rainfall amounts to more than 4 inches per month. The first of these steps is the hand picking of the hibernated weevils from the young plants at the time that squares begin to form. This step will pay if it is possible to find fifty or more weevils per acre at the time. In some cases more than 2000 weevils per acre have been thus picked and destroyed. The weevils may be crushed as they are captured or dropped into a bottle containing a little kerosene. The conspicuous sign of the presence of weevils at this stage of the cotton is the appearance of small, black, dead leaves in the tender bud of the plant. In this work it is advisable to use the hoop and sack described below.

*Destroy Infested Squares.*—This step in weevil control is also necessary where weevils abound early in the season, especially where the rainfall is heavy so that the surface soil is moist most of the time or when the air temperature in the shade does not go much above 90 degrees F. as lower temperatures are not likely to kill many of the weevil stages even if the ground is dry. Picking of infested squares should be done thoroughly, taking the evidently injured squares from the plants as well as the fallen squares from the ground. It should be begun within ten days after the appearance of the first bloom in the field and repeated every fifth day for four to six weeks.

For fuller details regarding these two special practices see Alabama Press Bulletin No. 64.

*Making Hoop And Sack Outfit.*—In the collection of weevils, and also of many of the infested squares, it has been found recently in Louisiana that a simple home-made device, bearing this name, is very helpful. The hoop should be a large, stout, wooden hoop some 20 or 22 inches in diameter, such as may be obtained anywhere from old sugar barrels. The sack may be made of unbleached sheeting, drilling or of Osnaburg duck.

Get a strip of cloth about eight feet long. Double this strip in the middle and sew up each side to make the bag. Two widths of 32 inch cloth will go around a 20-inch hoop, and of 36-inch cloth for a 22-inch hoop. It is advisable to make the sack somewhat smaller at the bottom than at the top. So in sewing, start about six inches in from each bottom corner and run outward gradually so as to make the sack full width at one foot from the top; continue at full width for six inches



## PLATE VI.

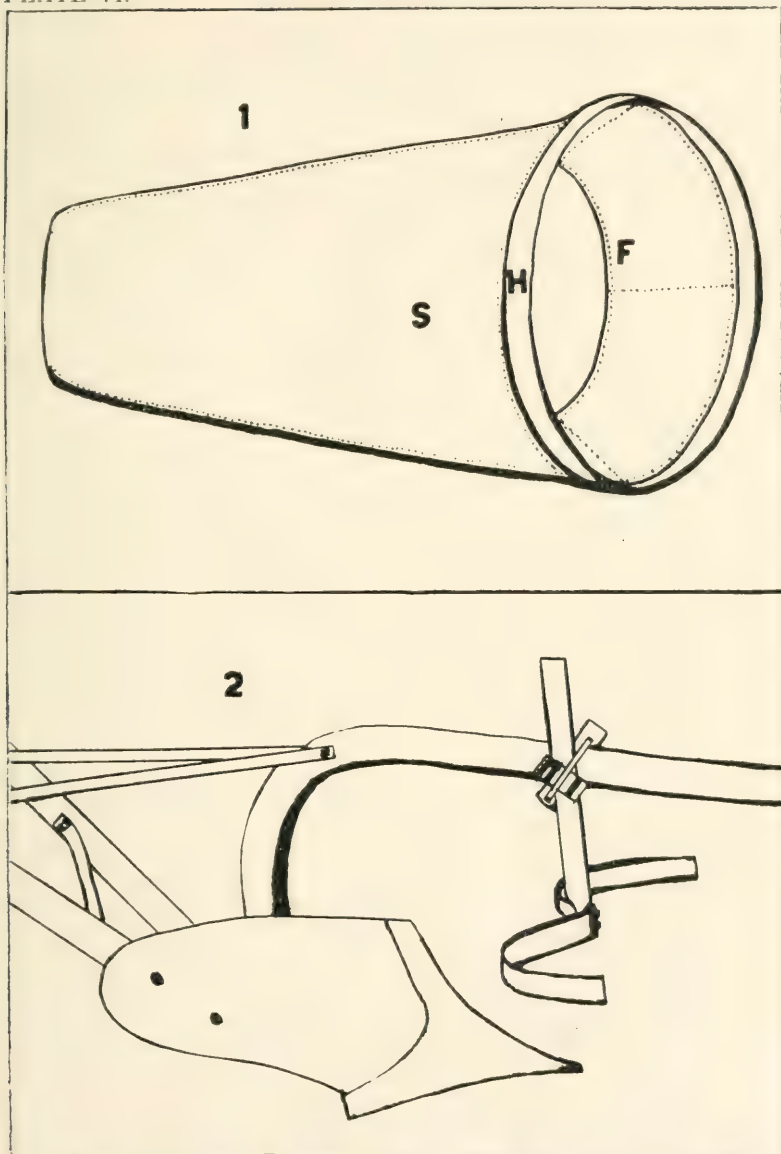


Figure 1, Hoop and sack outfit: (F), flap, (H), hoop, (S), sack. Sew along dotted lines. Fig. 2, Stalk bender, attached to plow beam. (Original).

and then run inward to a point two inches in from the top corner. Next fold the sack with the seams together and take in two more darts at the top corners running from the edge at six inches below the top to two inches in at the top. Trim off the triangular pieces of extra cloth at the lower corners of the sack and at the four darts at the top. Then trim off the top evenly and run a half-inch hem around the top to prevent raveling and to strengthen the top. After this has been done, place the hoop in position within the top of the sack, folding the cloth down over the hoop so as to make the top form a flaring, projecting flap extending to about six inches below the hoop. The object of this flap is to prevent the weevils crawling out of the sack as readily as they can do if there is no such flap present. Finally, stitch the flap to the side of the sack just below and so as to enclose the hoop. All of this sewing can be done either on a sewing machine or by hand. It will require hardly thirty minutes to make this outfit and the cost will range from 25 cents, if sheeting is used, to about 35 cents with the Osnaburg. A clearer understanding of the construction may be obtained by reference to Plate VI, figure 1.

*Using Hoop And Sack Outfit.*—Beginning at the time that the first small squares appear, go over the cotton to collect as many as possible of the over-wintered weevils before eggs are laid.

With one hand the hoop is held close against the base of each plant, while with the other hand the plant is bent into the open mouth of the sack and shaken vigorously. A second collection should be made in the same manner about ten days after the first bloom appears and subsequently every five or six days as advised above. With this outfit many infested squares, which are nearly ready to fall, will be shaken into the bag with the weevils and those already on the ground should be collected also. Weevils and squares are kept shaken down into the bottom of the sack where they may be somewhat confined by a turn in the sack. Every few rows the contents of the sack should be emptied into, and submerged in, a tub or barrel containing water with a little kerosene on top. The oil will kill the weevils and the stages in infested squares may be destroyed by burying them later under more than six inches of solidly packed earth. With this outfit a laborer can go over two or three acres of cotton per day and he will probably get many more we-

vils than he could secure by hand picking.

*Machines For Collecting Weevils.*—A great many machines have been invented, and tested more or less thoroughly, to do this work. None has yet shown itself capable of doing as thorough or economical work as can be done by the hand method, although some of these machines are said to have cost a thousand dollars apiece to build them. Planters will do well to get a disinterested opinion from the Entomologist regarding the merits of any boll weevil machine before investing in one.

*Summer Control Difficult and Expensive.*—Although no summer practice is nearly as effective as is the early fall destruction of stalks for holding the weevils in check, the measures mentioned may be profitably followed under especially favorable conditions. The deciding factors are usually an available labor supply that costs little if any extra, and a moist condition of the surface soil when squares begin to fall. While it will not often pay to employ hands to collect weevils or to pick up fallen infested squares at even 75 cents per day, it will pay to collect them if the children in the family can do the work. Most cotton squares fall to the ground in about ten days after the weevil eggs are placed in them, and when the grub is about half grown, Plate III, figure 5. In from five to ten days more they may produce adult weevils. If it is very hot and dry and the surface soil forms a dust mulch, fallen squares exposed to the direct sunshine would be "baked" so that all weevil stages in them would be killed. It would not then pay to pick up squares. If done at all, it pays to get the first fallen squares, to pick also all evidently infested squares from the plants and to do the work thoroughly. Naturally these summer methods are much more expensive than the relatively simple matter of early fall destruction of the cotton stalks. The expense of collecting weevils and squares, even with the hoop and sack outfit, ranges usually from \$2 to \$5 per acre.

*Insecticides Not Helpful.*—No direct insecticidal practice can be recommended, as it is practically impossible to reach the weevils on account of their peculiar feeding and breeding habits. This is the reason why we must depend upon cultural methods for weevil control. If the cultural methods here outlined are faithfully practiced then there should be little difficulty



in producing increasingly profitable crops of cotton in spite of the boll weevil. Alabama Press Bulletin No. 77 deals with this question of insecticides.

*Pick Cotton Promptly.*—It should need no argument to prove that cotton should be picked out promptly after it opens. There is nothing to gain and much to lose by allowing it to hang and weather and beat out onto the ground even where there are no weevils. But where weevils occur, prompt harvesting cannot be too strongly urged. This is to clear the way for the early destruction of all green cotton. We cannot even afford to wait for the last few bolls or "scrappings," as this waiting delays the work of destroying stalks and the resultant increased injury to the next crop of cotton from the larger number of weevils that will survive is likely to amount to many times the value of the "scrappings" saved in the fall.

*Select Seed For Weevil Resistance.*—One of the most important and best paying steps in making larger yields and earlier maturing crops is the careful selection of seed. You cannot afford to continue to plant "gin-run" seed. You may pay fancy prices for high-grade seed to start with, but after a few years without selection and with careless ginning, it will be badly mixed and give much poorer yields. Use your own brain and keep the money in your pocket instead of paying for the use of some other man's intelligence and industry. Get good seed to start with, then select carefully for next year's planting taking the best and earliest bolls from plants of the most desirable type. Remember that this "type" under boll weevil conditions must produce the maximum possible crop of bolls in the shortest possible time after squaring begins, with a foliage that will not shade the ground too heavily. Such plants will usually be of medium size, with numerous fruiting branches and few, if any, vegetative branches. Bolls will be set closely together on the branch and will be "bunched" in closely around the basal and inner two-thirds of the mature plant. These bolls may have thick hulls but in any case should become immune to weevil attack within the shortest possible time after they are set. Hairy stems are also desirable as this character hinders the weevils decidedly in their movements over the plant and therefore delays their working. A desirable type of plant is shown in Plate V.

*Prepare to Destroy all Green Cotton as Early as Possible to Save Next Year's Crop.* Having selected seed for next year's planting and harvested the main crop, then the next step in point of time is to starve the adult weevils which can feed only on cotton, and prevent the development of thousands of weevils in the late fall growth of squares and bolls which never can do anything but breed weevils. Do this to save next year's crop. When you cannot possibly raise a top crop of cotton, why raise a bumper top crop of weevils instead?

### WEEVIL CONTROL BY EARLY FALL DESTRUCTION OF COTTON.

*Stalk Destruction is Usually Possible.*—No late maturing cotton occurs where the weevils are abundant. In fact, under weevil conditions the whole tendency is toward the production of a very early maturing crop. With the reduced acreage in cotton, it then happens that the picking season ends, cotton fields can be cleaned up and a winter-growing cover crop may be planted many weeks earlier than such things can usually be done before the weevils arrive. The longer the period between the removal of green cotton plants and the occurrence of killing frost the more complete will be the destruction of the weevils and consequently the less will be the weevil injury to the following crop of cotton. To be fully effective, stalk destruction should occur a month before frost and must include the destruction of squares, bolls and foliage with no chance of sprouts appearing later to maintain the surviving adults until frosts occur.

*Most Important Step in Weevil Fight.*—Will you choose to destroy the weevils in the fall or have them destroy your cotton crop next year? The earlier stalks are destroyed, the fewer weevils will survive the winter and the smaller will be the damage to the succeeding crop. This early fall destruction of the stalks is the most important single step in the entire fight against the boll weevil. Wherever weevils occur, or may enter new territory, stalks should be destroyed if possible at least a month before frost.

*Why Stalk Destruction is so Effective.* There are three principal reasons why early stalk destruction is more effective than is any other practice in directly controlling the boll weevil: First, it completely pre-

vents the late fall breeding. These late-developed weevils are the ones most likely to survive the winter as they have not exhausted their vitality by long flights or by extensive deposition of eggs as have the older weevils. Second, few full-grown weevils can live for more than three weeks without food before killing frosts occur. After frosts the weevils may live for more than six months without tasting food. Early destruction of stalks therefore forces the weevils to move for food to other fields where stalks are still standing or leaves them to starve before it becomes cold enough for them to live without food. Third, cleaning up the cotton fields early in the fall removes the very best winter shelter condition that the weevils could possibly find and therefore reduces directly the percentage of weevils surviving the winter.

The combination of these factors makes the early fall destruction of green cotton the most effective method yet found for fighting the weevil successfully. It is also the most economical method for controlling the weevils as it need not involve any real extra expense.

*Records From Texas and Louisiana.*—More than 175,000 definite observations made in Texas and Louisiana during several seasons and in a number of widely separated localities gave the results shown below for each 1000 weevils present when their food supply was removed.

| <i>All cotton stalks<br/>destroyed by</i> | <i>Number of weevils<br/>per thousand<br/>surviving winter</i> |
|-------------------------------------------|----------------------------------------------------------------|
| September 30                              | 2                                                              |
| October 15                                | 21                                                             |
| October 31                                | 68                                                             |
| November 16                               | 121                                                            |

What was found to be true in so large a number of observations, in many localities and in an average of several seasons West of the Mississippi River is doubtless approximately true also here in Alabama and we may therefore expect a similar survival under average winter conditions here.

### THREE METHODS OF DESTROYING STALKS.

There are only three methods of stalk destruction to



be considered. They will be mentioned in the order in which they have been commonly practiced, which is, however, the inverse order of their real value.

1. *Grazing Not Recommended.*—First, the grazing off of cotton fields after the crop has been gathered. This practice is old and has been quite generally followed, so far as there was livestock available. The grazing off of weevil-infested cotton fields destroys the stalks only slowly and partially. There is always sufficient green cotton present somewhere in the field to keep alive the weevils that are already adult or which may emerge before frost occurs. The only condition under which grazing can have much value is in the very exceptional cases where the farmer can turn in sufficient stock to graze off all green cotton within a few days time. The grazing method is therefore unreliable, unsatisfactory and cannot be recommended.

2. *Burning of Stalks.* This method, preferred in the past because no better way was then known, involves the cutting or uprooting, piling and burning of the cotton plants. It has many points of advantage in controlling the boll weevil, but has also the disadvantage of destroying a considerable amount of vegetable matter which is badly needed for building up the soil and increasing its productiveness. For this reason we recommend burning stalks only where weevil control by deep plowing is impossible.

*Preparation For Burning to Leave Ground Smooth.*—To prepare stalks for burning the farmer may uproot or cut them in several ways. (a) Where a cover crop, such as crimson clover, has been worked in at the last cultivation or before the cotton has been completely picked out, the ground may be left in a smooth, practically undisturbed condition and the cotton stalks removed without injuring the cover crop by simply chopping off the stalks just below the surface of the ground by using sharp, heavy hoes. The stalks may then be piled by hand on the field, or better removed from the field by dragging them off with a hay-rake. One man can chop out the stalks on an acre of average sized cotton in a day. The expense of this method of destruction is therefore not excessive and no extra or unusual tools are required.

*A-Shaped Stalk Cutter.*—This stalk cutter, described in Alabama Circular No. 33, is arranged to cut two rows at a time throwing the stalks from two rows together

into a windrow. As its efficiency depends upon the maintainance of fairly sharp, cutting edges on the two steel blades that cut the stalks just below the surface of the ground, it is not adapted to use in stony or coarse sandy soil as such soil quickly dulls the knives. It cannot be used conveniently where stumps are very abundant, or on steep hillsides but on fairly level, loamy bottom lands it may place stalks in position for burning more cheaply than it can be done by any other method.

*Burn as Soon as Foliage and Tips are Dry.*—Stalks to be burned should be placed in position to burn while still green to avoid scattering foliage, squares, bolls, etc. The weevils are then concentrated upon the rows or piles of stalks and nearly all of them will remain there until burning can be accomplished. Burn as soon as the foliage is dry enough to produce a good heat, and while the stalks themselves are still too green to burn cleanly. This saves a considerable part of the vegetable matter. Run the fire along the windrows with the wind to burn as fast as possible.

*Burning Destroys Weevils in Several Ways.*—Burning stalks destroys weevils in a number of ways. First, it will get immediately a large proportion of the weevils already adult and active. Second, it will absolutely destroy all immature stages in squares and bolls. These stages developing into late weevils would be the ones most likely to survive the winter. Third, by the removal of all green cotton, weevils which escape the fire will be likely to starve to death before they succeed in finding food. Fourth, the destruction of the stalks removes a large proportion of the material which provides most favorable shelter for the weevils during the winter, and weevils still remaining in the field are therefore most likely to perish, or if driven out of the field, less likely to find favorable shelter.

3. *Plowing Stalks Under Early Recommended.*—The best method of stalk destruction, from the combined view point of good farm practice and also of effective weevil control, is to plow the stalks under deeply and completely as early in the fall as may be possible. This preserves the full humus-making capacity of the cotton stalks, grass and other vegetable matter that may be present. If buried under four, or more, inches of soil so few weevils will be able to escape that weevil control will be practically complete.

*Larger Plows and More Mules Needed.*—The old combination of one small and underfed mule, a light plow and an indolent farmer seeking to get along with the least work possible has never produced either an economical or a profitable type of agriculture in the South. Such a combination insures a poor farm and a farmer who is steadily growing poorer. It is important that farmers should accomplish more work at less expense and this they can do by using more mules and better implements. This is a very important matter in making a successful fight against the boll weevil.

*Weevils Escape if Plowed Under Shallow.*—It is not possible to do a satisfactory job in trying to plow under cotton stalks in the fall with a light, one-mule plow. With such plowing a large proportion of the adult weevils may escape to find food until frost and then hibernate elsewhere. Even the immature stages in squares and bolls buried lightly may mature and the weevils escape under such conditions.

*Stalk Chopper Not Necessary for Good Work.*—It is an easy matter to turn under completely cotton stalks of small size but it has been rather a difficult matter heretofore to do satisfactory burying of green cotton stalks of more than average size. Some farmers have used cotton stalk choppers to cut down the stalks before trying to plow them under. This method involves the extra cost for a rather expensive chopper and an additional operation for a man and two mules in cutting down stalks.

*Stalk Bender is Cheap and Effective Attachment to Plow.*—The expense thus involved for the chopping of stalks can be saved by the use on the plow of a very simple attachment known as a "stalk bender." This inexpensive device, produced by an Alabama man as a result of the campaign for cotton stalk destruction in the fall of 1915, is a very simple iron attachment, so made that it can be clamped to the beam of any plow in the position ordinarily occupied by the coulter. Plate VI, figure 2. It gathers in cotton stalks or similar growth and bends it flat upon the ground so that the plow-share following closely behind it turns the soil and completely buries the stalks, grass, etc., in the bottom of the furrow. With this device attached to a good two horse plow it is now possible to completely bury the largest cotton stalks without any preliminary use of the stalk chopper. With this device, its cost

may be saved in one or two days of plowing and at the same time an unusually good job of stalk destruction is done. The address of the makers of this stalk bender will be given to anyone requesting it of the Entomologist.

*Best Method for Weevil Control in Fall.*—The satisfactory burying of green stalks now possible with this inexpensive attachment to the regular plows, the economy in time and labor required, the possibility of preserving all vegetable matter for soil building while at the same time obtaining a very satisfactory fall control of the weevils: these together with other favorable considerations which we have not space to mention here, lead us to recommend the early fall, deep plowing under of stalks with the aid of the stalk bender as the best method now known for the fall campaign against the boll weevil. In our opinion this method avoids the chief objection to the burning of stalks: the destruction of humus-making vegetable matter which most southern soils need very much. It is in line with the best, most progressive and most profitable farm practice of the present time. It will be adopted increasingly by men who own and operate their own lands, by those working under a share rental system and by standing renters who can either make their arrangements by October first or who can arrange for a lease period of more than one year.

*Annual Lease a Hindrance.*—For the best interests of the land owner who is interested in having the soil in which his capital is invested built up, improved in productiveness, and increased in either sale or rental value, and also of the ambitious renter who desires to increase his income and make a better home, with a better living and better educational opportunities for his family, the annual standing rent lease system is the poorest system imaginable. Under it, we can be certain that practically every tenant is going to take out of the land every thing that he can get and that he will put into it nothing that will not yield him fullest returns the same year. This means a poor system of farming; a depleted, increasingly unproductive soil and lower crop production at greater expense; a poorer farm and a poorer farmer who must keep moving from place to place in a vain search for a better opportunity under a hopeless system.

*Clean Up The Farm: Remove The Stumps.*—Besides



the destruction of stalks, there are a number of other points included in what may be called clean farming which should be carefully looked after in fighting the weevil. The presence of stumps or dead timber in the field, while bad agricultural practice under any conditions, is especially favorable to weevil hibernation. Dr. S. A. Knapp estimated that the presence of stumps in a field costs the cotton farmer on the average \$3 per acre each year. With the boll weevil present, they may cost far more than this, because of the shelter which the weeds, growing around them, may give to hibernating weevils. They cost also by preventing the use of improved machinery, which is especially desirable in boll weevil territory.

*Clean Ditches, Turn Rows and Fence Lines.*—In general, we would say clean up all kinds of rubbish along ditches, terraces, turn-rows, and around the edges of the field to reduce the chances of weevils hibernating successfully. This will decrease the injury done by other insects besides the boll weevil.

*Fall Campaign Most Economical.*—From the standpoint of combined effectiveness and economy the early fall is the best time in all the year to make the fight against the boll weevil. We have seen (page 48) that where stalks are destroyed by October first only a fraction over one per cent. of as many weevils will survive the winter as will survive if food is left for them until the middle of November or until killing frosts occur. Therefore, with early fall stalk destruction the weevil fight is made far easier for the following spring and summer. The fall campaign is in line with the best farming methods and will involve hardly any extra expense to obtain effective weevil control. If the fall campaign is not made, then the weevil survival, with average seasonal conditions, will usually make it necessary to pick weevils from the young plants at the time squaring begins (see pp. 41-44) and also to pick and destroy infested squares repeatedly during the first six weeks of the fruiting season (see page 42). The necessary cost for those two admittedly incomplete methods of weevil fighting will usually be at least \$3 per acre. In most cases where the fall campaign is made it will be found unnecessary to make this costly summer fight. The direct saving in labor and expense is evident but this is not all. We should also consider the value of the increased yield which

will be obtained as a direct result of the more effective control of the weevil that is obtained from making the early fall campaign.

*It Pays to Destroy the Stalks Early in Fall.*—From the many demonstrations which have shown the great value of early destruction of stalks in fighting the weevil, we may consider one definite case in which the records were carefully kept and definitely authenticated by the U. S. Bureau of Entomology. On the Gulf coast of Texas in the fall of 1906, all of the planters in an isolated locality, controlling together about 400 acres of cotton, were persuaded to destroy their cotton stalks by burning during the first ten days of October. No cotton was grown nearer than fifteen miles, and here across a bay a suitable check area was found. In the check field stalks were allowed to stand as usual until planters were ready to begin their spring work. Without making any other changes in the practice usually followed by the planters in each of these localities, the yield obtained in 1907, upon the 400 acres averaged better than two-thirds of a bale per acre in spite of the fact that the soil was rather poor and sandy. No weevils could be found in this tract until after the first week in July. Upon the check area hardly one-half of this yield was obtained, although the land here was richer than upon the 400 acre tract. Weevils were abundant on the check area from the time cotton was planted while where stalks were destroyed no weevils could be found until about July 10. The difference in yield can be attributed only to the difference in the manner of handling the stalks the preceding fall.

*\$20 Per Acre on 400 Acres.*—At the market value of cotton that year, the increased yield upon the 400 acre tract due to fall destruction of the stalks was worth fully \$20 per acre, or more than enough to have bought the land upon which the crop was grown. Somewhat similar good results can be obtained anywhere if the fall campaign can be made generally.

*Benefit Certain to Man Who Makes The Fight.*—Many farmers ask "what good will it do me to destroy my stalks in the fall if my neighbor does not destroy his likewise?" The answer is that the man, farmer A, who makes the fight will receive practically all of the benefit from what he does regardless of the inaction of his neighbor, farmer B. This is true for several rea-

sons. First, weevils escaping immediate destruction in field A, where stalks are destroyed early, can live at that season of the year for only about two weeks without food. They must therefore fly to the undestroyed cotton of the neighboring field B, to find food or they will starve to death before it becomes cold enough for them to live without food. The number of weevils hibernating in or around field A, therefore, becomes negligible while that in field B is increased by weevils coming from A. Second, the winter shelter conditions are most unfavorable for weevils in field A, and most favorable in field B where stalks are permitted to stand. (See page 34). Third, we shall assume that both farmers are likely to plant at about the same time in the spring. Weevils emerging from or around field B will therefore find food close by and very few will therefore go further to reach field A. This is true especially because weevils do not fly in the spring nearly as readily as they do in the fall.

In a most careful study of this matter, using marked weevils, a number of individuals were followed in their movements in a cotton field for more than six weeks in the spring. During this time they had not moved more than fifty yards from the point at which they started. Therefore the movement from field to field is slight as a rule so long as uninfested squares continue abundant where the weevils occur.

*Community Cooperation Best.*—No man should delay in making the fight because of the lack of co-operation on the part of his neighbors but it is unquestionably better for the whole community if general co-operation can be secured as the danger of an early reinfestation will be correspondingly decreased.

## PRINCIPAL FACTORS IN NATURAL CONTROL OF THE BOLL WEEVIL.

*Four Groups of Factors.*—There are four principal groups which include the most important of all the natural factors of control affecting the boll weevils. As a result of records made by the agents of the U. S. Bureau of Entomology, from the examination of more than 222,000 squares and bolls collected principally in Texas but representing also conditions in Oklahoma, Louisiana, Arkansas and Mississippi, it appears that these four factors are together responsible for the destruction of more than half of the weevil stages that

begin development. In the order of their general importance and with the average percentage of mortality caused by each, they are as follows. 1. Climatic conditions (especially heat and drought in summer), 25 per cent.; (2) Predacious insects ("fire ants" principally), 16 per cent.; (3) Plant resistance by proliferation, 12.5 per cent.; (4) parasites, 4 per cent. Naturally the mortality from heat and predatory ants is greatest among squares and small bolls which fall to the ground. These constitute about seven-eighths of the total number of infested forms. The work of parasites is greatest among the small portion (one-eighth) of forms which remain hanging, but dry up, upon the plant.

*These Factors Affect Weevil Injury.*—As a direct result of the varying influence of these factors in different sections and during different seasons in the same locality, the direct injuriousness of the boll weevil varies quite widely. Climatic factors affect the growth of the cotton plants as well as the development of the weevils. Conditions of frequent and heavy rainfall, with high humidity and warmth, produce naturally the maximum vegetative growth of cotton, or the largest weed, and also the maximum number of weevils with their consequent maximum direct injury to the cotton yield. Under such conditions the cotton crop is almost certain to be a failure. On the other hand, with a rainfall in June and July especially of less than four inches per month, and if good cultural conditions are maintained so that the plants may continue fruiting steadily, there should be no serious doubt of the possibility of raising a very good crop of cotton in spite of the weevils.

*Summer Control by Heat and Drought.*—Long periods of extreme heat and drought occurring early in the fruiting season are most effective in checking the multiplication of the weevils. To exert a very marked effect this period must extend beyond four weeks with maximum temperatures, as recorded by the Weather Bureau, ranging above 90 degrees much of the time. During the first month or six weeks after squaring begins, the plants do not shade the ground very much and weevil stages in fallen squares and small bolls may be more certainly destroyed by heat and drying than will be the case later in the summer when the ground is more completely shaded. This matter is quite fully



discussed in Alabama Bulletin No. 178. This summer control will never be as great in Alabama as it is commonly in Texas under their drier summer conditions.

*Winter Control by Cold and Wetting.*—The other extreme of climatic conditions may also exert a very important limiting effect upon the survival of weevils during their hibernation period. This is most effective, naturally in the extreme northern limit of their range, and in western Texas, Oklahoma and Arkansas especially, has doubtless been the most effective natural factor in limiting the spread of the weevils. Occasionally severe winter conditions seem to have reduced the infested area but in no case has this winter extermination of weevils been as widespread or important as in the case of summer control by summer heat and drought. As a general rule winter conditions of unusual severity simply reduce the number of weevils living through without really exterminating the species and it is not possible therefore to measure accurately the real value of such a control factor.

*Winter Temperatures Endured by The Weevils.*

From a study of Weather Bureau records for many years, it is quite evident that in western Texas, Oklahoma and Arkansas especially, the boll weevil has continued to exist, though in reduced numbers, in territory where the minimum winter temperature has fallen occasionally even slightly below zero Fahrenheit. This does not mean that boll weevils can survive actual exposure to zero temperature, as the shelter within which they are passing the winter may so modify the outside temperature that the actual survivors do not experience a temperature lower than 12 or 15 degrees above zero, F. Certainly where the winter minimum rarely falls lower than 10 degrees F. it may be expected that the weevils will survive the winter in considerable numbers. The records for Alabama show that during the past 24 years the winter minimum for the State has fallen below zero only in seven years and then it has been usually only in the extreme north-western corner or in the northern portion of the State.

*Weevils Now Exist North of Alabama-Tennessee Line.*—For several years now the weevils have maintained themselves at points which are farther north than any point in Mississippi, Alabama or Georgia and with the somewhat milder winters that occur in these states, it is evident that there is no good reason to ex-

pect that boll weevils will be unable to maintain themselves generally in even the northern-most portion of these states. Furthermore, we must face the fact that the boll weevil has shown a wonderful ability to adapt itself to colder climatic conditions as it has spread northward from Mexico through fully ten degrees of latitude. This adaptation may, in time, enable the weevil to survive in sections that it has not yet infested.

*Cotton Worm Stripping Controls Weevils.*—The effect of the cotton worm upon the boll weevil is a very interesting illustration of insect inter-relationship. Both of these species are confined entirely to the same food plant, cotton, although they attack different portions of the plant. They do not in any way attack each other directly, except that where stripping is complete the worms may consume squares which happen to be infested by the weevil. Either species occurring alone is rightly considered a serious pest upon cotton, but when the two species occur together, after half or two-thirds of the squares are infested by the weevils, the cotton worm becomes one of the most effective natural agencies controlling the multiplication of the boll weevil in the fall and thereby greatly reducing the number of weevils occurring the following summer. The benefit is not to the present, but to the succeeding crop and the cotton worm in boll weevil territory should not be poisoned after the boll weevil has infested half of the squares present but considered as a valuable friend and ally of the cotton farmer.

*Proliferation in Squares and Bolls.*—In response to the irritation or injury inflicted by the weevil to squares and bolls, there commonly occurs a very rapid formation of new cells in the effort of the plant to heal the wounds caused by the weevil. This process of cell formation is called proliferation. These new cells are thin-walled, large cells which form a soft, almost gelatinous mass and this condition may spread to a considerable distance from the point of attack and may ultimately affect the entire square or boll. The large, soft cells are sometimes formed so rapidly and abundantly that the mass exerts considerable pressure, even bursting through the walls of the affected forms. It thus happens that the weevil eggs may be crushed before they hatch or if they hatch, the grubs or pupae, and sometimes even the newly formed adult stages, will be crushed and destroyed by this abundant prolif-

eration. This plant factor is generally responsible for the destruction of about 12 of 13 per cent. of all weevil stages starting to develop and is therefore one of the most important natural factors in weevil control. Proliferation commonly extends beyond, and exceeds by its own injurious effects, the direct injury which might have been caused by the weevil stage which started it. The abundance of this proliferous cell formation appears to vary with different varieties of cotton and also in the same variety under different conditions of soil moisture.

*Predacious Ants Helpful Insects.*—About thirty other insect species feed more or less upon some stage of the boll weevil. The most important predatory enemy is the little "fire ant" which occurs already distributed through the cotton belt. These ants occur on most types of soil but not everywhere in equal abundance. Where they are numerous they may exert a very valuable control effect upon the boll weevil. These ants are partly, at least, carnivorous and learn to cut their way into the fallen infested squares especially and there feed upon the helpless, tender grubs and pupae of the boll weevil. Occasionally these ants have been found to destroy more than half of the weevil stages in fallen, infested squares but as a rule their control ranges between 12 and 20 per cent. The holes made by ants entering squares resemble superficially the exit holes made by weevils as they emerge but a close examination of the interior of the weevil cell shows that, where ants have entered, the cell is left practically clean and empty. On the other hand when the weevil has emerged there will be left in the cell the remains of shed skins from the weevil stage as it transformed, some conspicuous white particles of excrement voided by the weevil before it ever fed and the fine material torn away by the weevil as it formed the emergence hole through the wall of its cell and the square. Many other species of ants do a similar but less common good work and a number of other insects feed occasionally upon either adult or immature stages of the weevil.

*Parasites Are Not Dependable.*—More than twenty-five different species of insects and four species of mites are known to attack the boll weevil as true parasites. These parasites have other native hosts and simply include the boll weevil as it comes within their range. Parasites attack more commonly the weevil

stages in squares and small bolls which dry up but remain attached to the plants. Naturally parasitism may increase somewhat as the weevil infestation becomes older but in no section have the parasites ever shown ability to control the boll weevil practically under natural conditions in the field. Parasite multiplication must necessarily follow that of its host. Their occurrence is always uncertain and cannot be determined by the ordinary cotton grower. The parasites like the predacious insects must be considered by the farmer as his friends and helpers but he can never afford to neglect the certainty of control by cultural methods for the uncertain and remote possibility of control by any natural enemies. As a general thing parasites have accounted for less than six per cent of the boll weevil stages.

*Birds.*—More than fifty different species of birds have been found by the U. S. Biological Survey to have fed occasionally upon boll weevils. Most of these capture weevils during their period of spread in the fall of the year. Few birds occur in cotton fields until after the crop is laid by and their attack upon the weevil in the spring and early summer is insignificant. Among these birds the orioles have appeared to be the most abundant feeders on weevils during the summer months and the blackbirds and meadow larks during the winter months. Valuable as the quail is from other viewpoints it is not important as an enemy of the boll weevil. The quail feeds quite largely upon insects of various species as well as upon weed seeds, etc., and is entitled to the highest consideration as a beneficial and valuable game bird. The help of birds as well as of insect predators and parasites is welcome but not a certain dependable natural factor in boll weevil control.

*Cultural Methods of Weevil Control More Certain.*—After all that we have written about these most important factors in the natural control of the boll weevil we wish to emphasize the fact that they are to be considered only as additional to the far more certain control by artificial cultural methods. Natural control operates as surely, and it may be as largely, in addition to what the farmer is able to do for himself. It is possible for the farmer under average conditions to assure himself a good crop in spite of the boll weevil, so far as seasonal or climatic and soil conditions may



permit, but it is only by utilizing the factors of hard, intelligent and timely work and never by depending upon a kind Providence to do it for him while he loafs two-thirds of the time.

## ESSENTIALS TO SUCCESSFUL WEEVIL CAMPAIGN

1. *Hold Farm Labor.*—This is a matter of the utmost importance as land without labor to work it becomes nonproductive and unprofitable. It is possible to keep labor on the farms and to readjust our farming system so as to minimize boll weevil damage and soon increased prosperity will be enjoyed. But if the labor once moves out of a community, the fields are allowed to become brushy, the unoccupied cabins decay rapidly, roads are neglected, the value of land goes down and it soon becomes a very difficult matter to get any good labor back into such a community. The sections which have suffered most heavily from the weevil invasion lost far more because they let their labor go than from any direct injury done by the weevils.

2. *Smaller Acreage and Better Cotton.*—Reduction in acreage planted in cotton to what can be given the better care that is absolutely required under weevil conditions is a long step toward success. The experience of large numbers of the most progressive and successful planters in old infested territory, especially where the rainfall is less than 16 inches during June, July and August, proves conclusively that cotton culture on a small scale can be continued profitably in spite of the boll weevils where such methods are followed as have been recommended in this bulletin.

3. *Increase Food, Forage and Livestock.*—It becomes necessary for the farmers to learn to raise as much as possible of their food and forage crops instead of depending upon the proceeds of their cotton crop to buy such foodstuffs. The reduced acreage in cotton leaves land available for such crops and for pasturage. We now know that Alabama farmers can produce as large a variety of such crops as can be grown in any state in the Union. Many of these crops, or combinations of crops which can be produced in a season in place of so much cotton, will yield a much higher margin of profit per acre than cotton has ever yielded even at a price of better than 12 cents per pound. Instead of sending out of the State possibly more than \$100,000,-

000 a year for food and forage as we have been doing under the all-cotton system, most of this immense sum can be kept at home as Alabama learns to feed herself.

4. *Reducing Advances on Crop Liens.*—Necessarily for the protection and best interests of both the farmer and the advancing party these advances must be reduced in weevil territory. The reduction should be made gradually during a period of years to enable both parties to become accustomed to the new conditions and to institute such changes as are required thereby. Through it all there must be one common purpose to stand by each other loyally for the ultimate good of both parties. One imperative condition in these reductions is that they shall not be made complete at once or carried to such an extent as to seriously cripple the farmer in his production of farm crops or other desirable products. The tenant farmer or cropper must be willing to meet the land owner, merchant or banker at least half way in making these changes. Advances should be conditioned upon the farmer making such changes in his system of farming as the local situation may require. As a rule, he should assure at least the raising of all corn and meat needed to carry him through the year. Rental systems may be changed from a standing rental to a share system or from the usual two bales of cotton per plow to one bale of cotton and the equivalent value of the other bale in other acceptable farm products or in cash. Show the farmer that something beside cotton can pay his bills and it will not be so difficult to bring about needed changes.

5. *Maintain Total Value of Farm Products.*—With a diversified system of farming even the average man can be helped through wise leadership to at least maintain the total value of his farm products for the year. The chances are good that this total value will be greatly increased while his living expenses are actually decreased and the standard of living for the whole community may be steadily raised.

6. *Provide Markets For New Products.*—In the disposal of the surplus from these new farm products the farmer needs the assistance of some of the local business men who may help him to solve the problem of markets. Many such products can be disposed of locally. Merchants can act as buyers or agents to collect products in such quantities that they can be shipped in quantity to more distant markets. It should be

the purpose in such cases to return to the farmer the largest possible portion of the proceeds as the greatest good for the whole community will be accomplished by helping and encouraging the farmer during this critical period of change. Numerous associations of farmers to co-operate in the selling of their products are being formed as a result of this need for markets. In the moving of such products locally, the matter of reasonable and equitable local freight rates is an extremely important factor.

7. *Longer Leases.*—The annual lease system is a constant and serious hindrance to desirable changes and improvements. Wherever possible, as with many of the best tenants on a farm, the lease period should be extended to three or five years. The farmer can then know that it will benefit him to go ahead with his fall campaign against the boll weevil, to use winter-growing cover crops, to build up his soil, to raise livestock, etc., as he will never do under the annual lease system. As a result the fertility of the soil can be most economically increased and at the end of the lease period the owner will have a more valuable piece of property than he would have under the annual system. Many large land owners are making this change.

8. *Improve Soil by Legumes and Livestock.*—The most economical, profitable and permanent system of farming includes both of these factors as essential elements in soil building. This is one of the most important elements in a successful campaign against the boll weevil as also in the solution of many of our southern rural problems. Many unprofitable fields might easily be converted into good permanent pastures with a combination of clovers and grasses, soil erosion can be checked, the commercial fertilizer bill can be greatly reduced and the real profit obtained from such fertilizers as are used can be increased as our farmers learn to increase the vegetable matter in their soils through the wise utilization of legumes and livestock.

9. *Alabama Must Feed Herself.*—Such changes will carry us a long way toward the fulfillment of this slogan. The coming of the boll weevil is helping us to realize the necessity for it as we never have before. Prosperity through the State as a whole will increase as we approach this standard, for the welfare of the

town and city, of the business and professional man as well, is ultimately conditioned upon, and largely measured by, the preceding prosperity of the farmer.

10. *Make Farm Life Satisfying.*—It is not enough, however, for us to look merely at the size or variety of farm crops or even at the amount of profit that the farmer may obtain from his year's work. We cannot fail to realize that this alone will never solve what we consider today as many of our most important rural problems. There must also be the enlarging of the life of those living on the farms. This means the improvement of the means of communication by better roads, rural mail deliveries, telephones, etc. There must be the improvement of the rural school facilities so that the children of the farmer may have within their reach practically as good common school training as is open to the young people of the town. Poor country schools have been the cause of more of our best, most intelligent and most successful farmers leaving the farms and moving into town than all other unsatisfactory country conditions combined. We cannot expect this loss to the country to be stopped until the country school is greatly improved. The country church is another important factor that cannot be overlooked. A high moral atmosphere is one of the most valuable assets of any community and certainly no less so in the country than it is in the town. There must be a higher development of its social life in the country community. And finally, but by no means least, the increased prosperity of the farmer must find expression also in the improvement of the farm home. Betchouses, neatly kept and painted, with more conveniences and comforts in them, for the housewife especially, but for every member of the household as well, will go far toward making the farm life attractive and satisfactory. The health of the family must be safeguarded especially through the maintenance of simple and inexpensive sanitary closets, thus helping to save on doctor's bills and making the farm home a healthier and happier place in which to live.

Strange as it may seem to many, the coming of the boll weevil is clearly and definitely helping to bring about progress along every one of these lines, and the campaign that is made against the weevil is the agency through which many of these more satisfactory changes for our country life shall be accomplished.



**ALABAMA**  
**Agricultural Experiment Station**

OF THE

**Alabama Polytechnic Institute**

**AUBURN**

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**Wilt Resistant Varieties of Cotton**

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By

**E. F. CAUTHEN, Associate Agriculturist**

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# WILT RESISTANT VARIETIES OF COTTON

By

E. F. CAUTHEN, Associate Agriculturist.

## SUMMARY.

Cotton wilt and root-knot occur more frequently in the southern third than in any other part of Alabama. However, these diseases are also to be found in the central third, and on small widely separated areas in certain other counties still farther north. Cotton wilt is found most frequently in loose sandy land; it rarely occurs in heavy clay soil.

In total money value of lint and seed per acre a non-resistant strain of Cook, used for comparison, averaged in fifteen experiments \$26.78 per acre; while the wilt-resistant varieties averaged as follows: Modella \$28.96; Wood \$33.19; Dixie \$33.22; Cook No. 307-6 \$31.17; Covington-Toole \$34.42; Tri-Cook \$40.53 per acre. The range of gains from resistant varieties extends from 8.1 percent with Modella to 51.3 percent with Tri-Cook.

An average of the percentages of yearly loss of cotton plants in each variety from wilt is as follows: Cook (check), a non-resistant strain, 40.3 percent; Wood 15.1 percent; Modella 14.7 percent; Covington-Toole 10.5 percent; Cook 307-6 9.3 percent; Dixie 8.5 percent; Tri-Cook 7.3 percent; Dillon 5.4 percent. In the two experiments in which Dix-Afifi was planted, it lost no plants.

The wilt-resistant varieties of cotton used in these experiments differ slightly in their relative earliness.

In comparison with standard varieties like Cleveland, Cook and Triumph, most of them must be regarded as somewhat later in time of opening.

Among the resistant varieties tested, those ranking highest in total money value of seed and lint per acre are the earliest and turn out about 40 percent of lint.

This Station recommends to farmers who have cotton wilt and root-knot in their land that they employ, as a means of controlling these diseases, a simple rotation of crops (see page 88) in which are excluded those crops that have a tendency to increase these diseases. In this rotation, which includes cotton, only wilt-resistant varieties should be planted.

## THE NATURE OF COTTON WILT.

Cotton wilt sometimes called "black-root" or "blight" is a diseased condition of the stem, or roots of the plant. It makes its appearance frequently about the middle of May, and may continue through the remainder of the growing season. After a few days of hot rainy weather, the effects of the disease are most noticeable. The loss is greatest in wet years.

The disease is due to a fungus (*Fusarium vasinfectum*, Atk), which can live in the soil for a long time on decaying vegetable matter. It is propagated by means of tiny spores and other forms of fruiting bodies. This particular fungus seems to attack only the cotton plant.

In 1892 Prof. George F. Atkinson, while working at this Station described this disease. In 1898 Prof. S. F. Earle of this Station was called to investigate an outbreak of cotton wilt on the farm of Mr. James Hall at Midway, Bullock County. (1)

### SYMPTONS OF COTTON WILT.

The fungus enters the roots and stems of the cotton plant and its threads (mycelia) fill or block up the water-carrying tubes, thereby cutting off or interfering with the supply of food elements and water from the soil. The interference with the water and food supply soon causes the cotton plant to wilt.

When a cotton plant is severely attacked by this fungus, its leaves may suddenly wilt without any apparent cause and fall off, leaving only a dead stem standing. Sometimes only a small part of the plant dies. The remaining part may put on a new growth, but it will always remain dwarfed in appearance.

### EXTENT OF COTTON WILT IN ALABAMA.

Cotton wilt occurs in two-thirds of the counties of the State. It is spreading rapidly, and it seems a matter of a short time when it will have extended to all sandy soils on which cotton is continuously grown.

The disease seems severest on loose sandy soils, but it may occur on any sandy soil even though it has a clay subsoil. It rarely occurs on heavy clays. The worst infection is usually found where the sand has washed in and formed a very deep loose sandy soil.

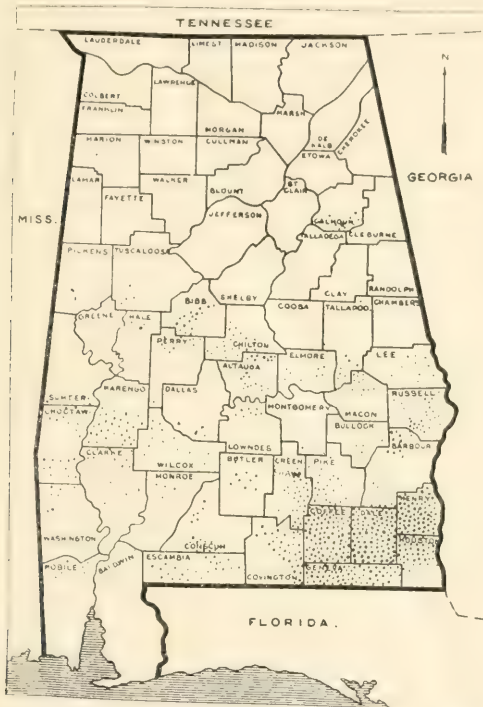
Wilt and root-knot are severest in that part of Ala-

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(1) Bul. 107, Alabama Experiment Station, p. 299.



lama lying south of a line drawn westward from Lee County to Sumter County. It is also found in small widely distributed areas in other counties.



The numerous dots on the map indicate that portion of the State where cotton wilt is severest.

## METHODS OF CONTROLLING COTTON WILT AND ROOT-KNOT.

### WILT-RESISTANT VARIETIES OF COTTON.

Wherever cotton wilt occurs, nematodes, which cause root-knot, are usually found. These worms enter the cotton roots, and cause abnormal growths, thus making it easy for wilt to gain an entrance into the cotton roots.

Most varieties of cowpeas, such as Whippoorwill, New Era, Red Ripper, and Clay are susceptible to root-knot, and when they are grown on infested land, the number of nematode worms or gall worms increases. Sweet potatoes, sugar cane, and many garden vege-

tables also serve to increase the number of gallworms. Such crops should not be grown on wilt-infected land, because they increase the number of nematodes in the soil and consequently increase the loss from wilt whenever cotton is planted on such land.

The common varieties of cotton differ widely in their resistance to wilt and root-knot. In those sections of the Cotton Belt badly infected with these diseases have originated varieties more or less resistant. Some of them have proven very profitable, even when grown on badly wilt-infected land. However, not all of the wilt-resistant varieties have desirable qualities, as earliness, easy harvesting, etc.

In 1911, this Station began a series of experiments in which many of the wilt-resistant or "anti-blight" varieties were planted side by side and carefully studied. The experiments were located on badly infected lands in different parts of the state, and their results, along with some recommendations, are published in this bulletin.

On the Alabama Experiment Station farm at Auburn there was then no badly infected wilt-land. Therefore, the experiments had to be located away from Auburn, where suitable lands and farmers willing to co-operate were available. Such men and locations were found in Butler, Lowndes, Lee, Macon, Pike, and Tallapoosa Counties. This experimental work has been supported by the appropriation made by the Legislature of Alabama in the "Local Experiment Law."

#### PLAN OF EXPERIMENTS.

A representative of the Station always selected the land, and laid off the plots. The preparation of the land and its cultivation were left to the farmer conducting the experiment.

The same kind of commercial fertilizer was used on most experiments. It was mixed at the Experiment Station, sacked and shipped to the experimenter. It usually consisted of 320 pounds of acid phosphate per acre, 160 pounds of kainit and 200 pounds of cottonseed meal. Some years 100 pounds of nitrate of soda was applied as a side dressing about the second or third cultivation.

The cotton seed of the different varieties were obtained from the originator or some reliable grower each year. The planting was usually done under the

supervision of a Station representative. An equal amount of seed was planted on each plot.

The experimenter was requested to thin the cotton in the usual way, leaving as nearly as possible a perfect stand and the same number of plants on each row. After the second cultivation or "dirtin'g the cotton", no more plants were to be destroyed by hoeing or plowing—a request not carefully complied with in every experiment.

About the middle of June a representative from the Station visited each experiment and made a careful count of all plants, both diseased and healthy, and pulled up all dead or nearly dead plants. On subsequent visits only the dead or nearly dead plants were pulled up and counted. The counts were made about 30 days apart throughout the growing season.

The plants that were not badly attacked or that had partly recovered are not included in the number of dead or nearly dead plants. The wide difference between the number of plants indicated by 100 percent of a stand of one variety taken as a standard and the small number of some other varieties is accounted for by the fact that many plants died either from wilt or from "sore shin" (*Rhizoctonia*) between the time of thinning and of the first counting. However, the percentage of dead or nearly dead plants represents the relative loss of the different varieties from wilt. The loss of plants from "sore shin" and cultivation is not taken into the calculation in making up the table of losses.

The picking and weighing of the cotton from each plot was done in most cases under the supervision of a representative of the Station.

All calculations of the yield and percentage of seed and lint are based on the ginning results obtained from those same varieties when they were included in the variety tests at the Experiment Station.

The percent of lint of most varieties is an average obtained from several ginnings, and is as follows: Cook 583, 42.8 percent; Cook 307-6, 39.5 percent; Covington-Toole, 39.1 percent; Dillon, 39.1 percent; Dix-Afifi, 30.6 percent (a long staple variety); Dixie, 35.3 percent; Modella, 35.6 percent; Tri-Cook, 41.5 percent; Wood, 35.1 percent.

The prices of seed and lint used in the table are those

that were employed in calculating the value of seed and lint in the variety tests at the Experiment Station during the years of the wilt experiments and are given in the following table:

| Year -----        | 1911    | 1912    | 1913    | 1914    | 1915    |
|-------------------|---------|---------|---------|---------|---------|
| Lint per pound -  | 9c.     | 12c.    | 13c.    | 6¾c.    | 12c.    |
| Seed per ton ---- | \$16.00 | \$16.00 | \$20.00 | \$16.00 | \$30.00 |

### COMPARISON OF DIFFERENT WILT-RESISTANT VARIETIES OF COTTON ON BASIS OF MONEY VALUE PER ACRE.

In the extensive wilt-variety test for the past five years we have compared the leading wilt-resistant varieties of cotton. These different varieties show some difference in yield and a wide variation in their resistance to wilt and root-knot. None of them are entirely immune to these diseases, but several of them are sufficiently resistant to make profitable crops of cotton even on the worst infected land.

In studying the table of "Total Values of Seed and Lint per acre" it should continually be borne in mind that it is practically impossible to find areas which are uniformly infected with these diseases and large enough to accomodate eight or ten different varieties in one-tenth acre plots. Therefore, one experiment is not sufficient for conclusions on the resistance of any one variety; but an average of several experiments, as recorded in the table below, is more valuable. A variety may lose a larger number of plants and produce less cotton in one experiment than in another. This larger loss in money value does not necessarily mean that this variety is less resistant than some other, but it may mean that it was planted on a worse infected area. However, when one variety in many tests falls below some other variety, it is doubtless due to its lack of resistance and productiveness.

### WILT-RESISTANT VARIETIES MEASURED BY THEIR MONEY VALUE.

The comparative value of the different wilt-resistant varieties of cotton in these experiments is shown in a table of total money value of seed and lint for each.



The money values are based on the actual yield of seed and lint cotton per acre. No corrections are made for the difference in stand found at the first count, which was usually about the middle of June, and none for the difference in stand at the time of picking. However, it should be borne in mind that at the time of thinning in nearly every experiment the stand was reported good or perfect.

The total value of each variety in the sixteen experiments recorded in the following table shows, in a fairly satisfactory way, its relative merit:

Table 1. — Total Value of Seed and Lint Per Acre

| Name of Experimenter                                        | Location    | Year | Names of varieties tested |              |                    |         |                                   |              |               |                 |         |              |
|-------------------------------------------------------------|-------------|------|---------------------------|--------------|--------------------|---------|-----------------------------------|--------------|---------------|-----------------|---------|--------------|
|                                                             |             |      | Dillon                    | Mo-<br>della | Cook<br>-<br>Check | Wood    | Cov-<br>ing-<br>ton<br>-<br>Toole | Tri-<br>Cook | Cook<br>307.6 | Cook<br>(Check) | Dixie   | Dix-<br>Affn |
| E. T. Peddy                                                 | Loachapoka  | 1911 | \$60.75                   | \$39.20      | \$38.50            | \$46.42 | \$47.96                           | \$57.02      | \$53.57       | \$46.13         | \$38.33 | %            |
| S. T. Slaton                                                | Loachapoka  | 1912 | 30.42                     | 25.24        | 28.18              | 39.15   | 36.63                             | 41.68        | 45.03         | 28.18           | 35.35   |              |
| Jas. T. Ramage                                              | Brundidge   | 1912 | 52.74                     | 35.56        | 20.14              | 38.54   | 50.27                             | 46.56        | 41.94         | 39.54           | 44.42   |              |
| W. J. Bridges                                               | Notasulga   | 1913 | 54.40                     | 46.10        | 43.29              | 56.21   | 58.86                             | 66.25        | 42.72         |                 |         |              |
| T. J. Burk                                                  | Tuskegee    | 1913 | 54.50                     | 41.54        | 14.74              | 33.34   | 50.57                             | 24.95        | 45.26         | 43.51           | 55.96   |              |
| Jas. T. Ramage                                              | Brundidge   | 1913 | 34.54                     | 27.79        | 6.81               | 29.14   | 27.28                             | 39.16        | 22.92         | 8.82            | 30.10   |              |
| Jim Whatley                                                 | Auburn      | 1914 | 12.94                     |              | 13.89              | 16.07   | 21.13                             | 19.32        | 14.72         | 15.99           | 14.64   |              |
| David Richardson                                            | Notasulga   | 1914 |                           |              | 22.46              | 23.63   | 18.97                             | 26.73        | 40.25         |                 |         |              |
| W. W. Thompson                                              | Liverpool   | 1914 |                           | 29.68        | 29.25              | 30.44   | 35.90                             | 29.00        | 30.54         | 28.08           | 31.56   | 29.07        |
| Jas. T. Ramage                                              | Brundidge   | 1914 |                           | 20.64        | 13.03              | 34.41   | 29.94                             | 31.49        | 36.36         | 14.24           | 29.31   |              |
| Joe Russell                                                 | Lowndesboro | 1914 |                           | 55.50        | 40.87              | 55.80   | 57.90                             | 70.33        | 58.31         | 47.43           | 39.90   | 39.58        |
| J. R. Stough                                                | Notasulga   | 1914 |                           | 14.89        | 9.60               | 19.36   | 14.99                             | 18.81        | 20.13         | 14.98           | 14.83   |              |
| David Richardson                                            | Notasulga   | 1915 |                           | 20.40        | 31.84              | 29.31   | 29.18                             | 40.68        | 18.39         | 37.73           | 38.39   |              |
| J. J. McGuire                                               | Notasulga   | 1915 |                           | 24.50        | 33.66              | 27.56   | 18.45                             | 42.38        | 26.39         | 33.66           | 28.82   |              |
| J. H. Reynolds                                              | Greenville  | 1915 |                           | 11.43        | 20.96              | 16.94   | 18.30                             | 22.67        | 15.98         | 20.25           | 16.32   |              |
| Average acre value of each variety                          |             |      | 28.96                     | 24.45        |                    | 33.09   | 34.42                             | 40.53        | 34.17         | 29.12           | 33.22   |              |
| Percentage of increase in acre value over average of checks |             |      | 8.1                       |              |                    | 23.5    | 28.5                              | 51.3         | 27.6          |                 | 24.0    |              |

*Mr. E. T. Peddy:* The experiment conducted by Mr. Peddy was located on a dark sandy soil with a yellow sandy subsoil. The land was not badly infected with wilt.

The average value of seed and lint of the two check plots was \$42.31 per acre; the average value of the wilt-resistant varieties was \$49.03, making an average difference of \$6.72 per acre in favor of wilt-resistant varieties. The four largest yielding varieties named in order are Dillon, Tri-Cook, Cook 307-6 and Covington-Toole.

*Mr. S. T. Slaton:* This experiment was located near the one conducted by Mr. Peddy, and on very much the same kind of land.

The total value of seed and lint per acre for Cook 307-6 was \$45.03; for Tri-Cook \$41.68; for Wood \$39.15; and for Cook (check) \$28.18. The gain from planting wilt-resistant varieties is measured by \$16.85 per acre from Cook 307-6, \$13.50 from Tri-Cook and \$10.97 from Wood.

*Mr. J. T. Ramage:* The experimental plots for 1912 and 1913 were located about one mile north of Brundidge on a sandy plateau-like elevation. The surface sloped slightly but not sufficient to wash; the fertility of all plots seemed about equal.

In 1912 the value of lint and seed per acre was \$52.74 for Dillon, \$46.56 for Tri-Cook and \$44.42 for Dixie. The average of the Cook (check) plots was \$29.84; this leaves a difference of \$22.90 in favor of Dillon; \$16.72 and \$14.58 in favor of Tri-Cook and Dixie respectively. A difference of \$32.60, or a gain of 162 percent is noted between Dillon and the check that suffered the greatest loss. In the 1913 experiment the advantage of the resistant varieties over the non-resistant variety is still greater.

In 1914 the experiments were transferred to a new location in the southern part of Brundidge. The land sloped considerably and was inclined to wash; its soil was dark sand, with reddish yellow sandy subsoil; the plots lay between two terraces and were fairly uniform in fertility.

The average money value per acre of Cook (check) was \$13.65, while the average of the resistant varieties was \$30.71 per acre, an increase of 125 per cent. in favor of the latter varieties. Among the wilt-resistant

varieties themselves there is the broad difference of \$15.72 by which Cook 307-6 exceeded that of Modella. The three largest yielding varieties named in order were Cook 307-6, Wood and Covington-Toole.

*Mr. W. J. Bridges:* This experiment is located on a dark sandy soil in Notasulga; the surface of the plots is almost level, with the exception of a shallow sag that runs across all of the plots. The field has been in cultivation many years.

The total value of the lint and seed of the Cook (check) was \$43.29 per acre, while the average of the wilt-resistant varieties was \$53.11, making an average difference of \$9.82 in favor of the latter varieties. The four largest yielding varieties, named in the order of their value, were Tri-Cook, Covington-Toole, Wood and Dillon.

*Mr. T. J. Burk:* This experiment is located on badly infected land in Tuskegee; the surface is almost level; the soil is a fine sand, or silt, and has been in cultivation for a half century or more; its fertility is above that of the average farm land.

The total value of seed and lint per acre shows a range in value from \$14.74 on the lowest check to \$55.96 on Dixie the highest wilt-resistant variety in this experiment. The second check was on land not badly infected with wilt. The average gain of all the wilt-resistant varieties over the average value of the checks is \$18.90 per acre.

*Mr. Jim Whatley:* This experiment is located about a mile and a half from Auburn on light sandy soil with a yellow subsoil. During the past ten years cotton has been grown on this piece of land alternately with corn and cowpeas and with corn and grain; the land has been fertilized liberally with commercial fertilizers, lot manure and leguminous crops.

The total value of lint and seed per acre from the first picking September 4th (the weights of the late pickings were lost) was \$21.13 for Covington-Toole, \$19.32 for Tri-Cook and an average of \$14.94 for the Cook (checks). Covington-Toole gained \$6.19 and Tri-Cook \$5.13 per acre over the average of the checks.

*Mr. W. W. Thompson:* This experiment is located at Liverpool, Macon County; the soil is a fine sand with a fine yellow sandy subsoil and has been cultivat-



ed in cotton many years. The 1913 experiment was located on badly infected land, while the 1914 experiment located on a different area showed very little wilt.

The yield of the 1913 experiment was lost through a mistake in picking. The advantage of one variety over the others in the 1914 experiment is not great.

*Mr. Joe Russell:* This experiment was located about a mile north of Lowndesboro on a dark fine sandy soil. It is typical of a badly infected section of Lowndes County. The fertility of this soil is above that of the average farm land.

Of the wilt-resistant varieties Dix-Affi made the least gain in money value over the non-resistant variety, while Tri-Cook made the largest gain, a difference of \$30.75 in favor of the latter variety. The average gain of the wilt-resistant varieties over the non-resistant is \$9.75 per acre. It is to be noticed that the money value per acre of the wilt-resistant varieties is sufficiently great to justify the growing of cotton on land highly fertilized, or naturally fertile, even if it is badly infected with wilt.

*Mr. J. R. Stough:* This experiment was located on badly infected soil about four miles from Notasulga. The land has been in cultivation many years and slopes gradually from one side of the field to the other. At the time of thinning the stand of plants was almost perfect, but at the time of the first count a considerable number of plants had died.

The money value of Cook 307-6 was \$20.13 per acre, while the average value of the non-resistant Cook (check) was \$12.29 per acre. An average difference of \$5.05 per acre in favor of the wilt-resistant varieties is shown in this experiment.

*Mr. David Richardson:* The experiments conducted by Mr. Richardson were located on a coarse sandy soil that had been in cultivation many years. The 1915 experiment which was in a different location was not badly infected with wilt.

In the 1914 experiment Cook 307-6 made a total value of \$40.25 per acre, while the Cook (check) adjacent made only \$22.46. This shows the advantage of planting a wilt-resistant variety.

In the 1915 experiment it is noticed that the difference between the non-resistant and the wilt-resistant

varieties is not wide. The greatest money value per acre came from Tri-Cook, which made \$40.68 worth of seed cotton per acre. The three best yielding varieties, named in their order, were Tri-Cook, Dixie and Cook (check).

*Mr. J. J. McGuire:* Mr. McGuire's experiment was located near that of Mr. Richardson's. The soil is light sandy with a yellow subsoil. The amount of infection was not very great, as is shown from the number of plants that died on the Cook (check) plots.

The money value of Cook (check) per acre is greater than that of the wilt-resistant varieties. This comes from the fact that the best yielding strain of Cook from the Experiment Station breeding test was used as a check in this experiment and that it possessed some immunity to black-root, as was found out later.

*Mr. J. H. Reynolds:* This experiment was located on a light sandy soil with a reddish subsoil about five miles west of Greenville. The land was badly infected with wilt.

The record of the first picking was the only one obtained. Almost all the late crop was destroyed by the boll weevil.

It is again noticed that the variety used as a check yielded a greater money value than most of the wilt-resistant varieties. This Cook (check) variety was the same as mentioned in the preceding experiment.

#### AVERAGE OF ALL EXPERIMENTS ON BASIS OF ACRE VALUES.

In an average of fifteen tests or more, the percentage of increase in crop value over the average of the check varieties indicates a difference in money value of 8.1 percent for Modella, 23.5 percent for Wood, 24 percent for Dixie, 27.6 percent for Cook 307-6, 29.5 percent for Covington-Toole and 51.3 percent for Tri-Cook. In total value of seed and lint per acre Dillon ranked high, and was probably the least susceptible of the wilt-resistant varieties to this disease.

Tri-Cook, Covington-Toole and Cook 307-6 in the fifteen experiments made an average acre money value of \$40.53, \$34.42 and \$34.17 respectively.

#### COMPARATIVE RESISTANCE OF DIFFERENT VARIETIES OF COTTON.

The table of "Percentage of Plants Dead or Nearly Dead" shows the relative resistance of the different

varieties of cotton in sixteen experiments, covering a period of five years. It is practically impossible to find areas that are uniformly infected with wilt and nematodes and that are large enough to accommodate eight or ten different varieties in one-tenth acre plots.

The following table shows the percentage of plants that died during the season. The first count was made about the 15th of June; the subsequent counts followed about thirty days apart during the growing season. All the dead or nearly dead plants were pulled up at each count so that they would not interfere with the next count. When a plant looked as if it might recover sufficiently well to produce fruit, it was not pulled up.

Table II.— *Percentage of Plants Dead or Nearly Dead up to the Last Count of the Season*

| Name of Experimenter       | Location    | Year | Names of Varieties Tested |              |                 |      |                      |              |               |                 |       |              |
|----------------------------|-------------|------|---------------------------|--------------|-----------------|------|----------------------|--------------|---------------|-----------------|-------|--------------|
|                            |             |      | Dillon                    | Mo-<br>della | Cook<br>(Check) | Wood | Cov-<br>ton<br>Toole | Tri-<br>Cook | Cook<br>307_6 | Cook<br>(Check) | Dixie | Dix-<br>Affi |
| E. T. Peddy                | Loachapoka  | 1911 | 1.4                       | 2.9          | 22.1            | 10.5 | 5.2                  | 6.0          | 3.7           | 15.1            | 3.7   |              |
| S. T. Slaton               | Loachapoka  | 1912 | 3.0                       | 28.0         | 35.2            | 17.2 | 25.1                 | 12.9         | 12.4          | 39.4            | 4.9   |              |
| Jas. T. Ramage             | Brundidge   | 1912 | 3.7                       | 10.2         | 68.2            | 11.6 | 10.8                 | 6.6          | 10.2          | 33.7            | 3.2   |              |
| W. W. Thompson             | Liverpool   | 1913 | 7.4                       | 29.2         | 68.0            | 27.5 | 9.6                  | 19.0         | 28.4          |                 |       |              |
| W. J. Bridges              | Notasulga   | 1913 | 3.5                       | 21.3         | 43.9            | 19.5 | 7.4                  | 12.0         | 14.3          |                 |       |              |
| T. J. Burk                 | Tuskegee    | 1913 | 3.0                       | 6.2          | 43.5            | 7.7  | 3.5                  | 5.2          | 5.1           | 24.5            | 18.7  |              |
| Jas. T. Ramage             | Brundidge   | 1913 | 15.5                      | 35.4         | 56.3            | 20.1 | 34.8                 | 9.5          | 10.1          | 33.2            | 20.0  |              |
| Jim Whatley                | Auburn      | 1914 |                           | 7.0          | 21.6            | 14.6 | 4.6                  | 0.9          | 6.1           | 3.0             | 2.7   |              |
| David Richardson           | Notasulga   | 1914 |                           | 13.8         | 42.4            | 14.4 | 4.9                  | 2.4          | 1.2           | 46.5            | 14.4  |              |
| W. W. Thompson             | Liverpool   | 1914 |                           | 1.6          | 8.0             | 1.4  | 1.1                  | 0.6          | 0.0           | 4.9             | 7.7   | 0.0          |
| Jas. T. Ramage             | Brundidge   | 1914 |                           | 34.3         | 82.5            | 21.8 | 8.6                  | 12.5         | 10.2          | 71.2            | 26.1  |              |
| Joe Russell                | Lowndesboro | 1914 |                           | 2.9          | 53.3            | 11.1 | 7.6                  | 3.5          | 5.4           | 15.1            | 6.8   |              |
| J. R. Stough               | Notasulga   | 1914 |                           | 10.1         | 45.2            | 21.5 | 16.8                 | 7.0          | 10.4          | 26.6            | 4.5   |              |
| David Richardson           | Notasulga   | 1915 |                           | 14.8         | 3.0             | 8.3  | 6.3                  | 10.1         | 1.8           | 46.5            | 1.2   |              |
| J. J. McGuire              | Notasulga   | 1915 |                           | 9.8          | 18.9            | 13.2 | 15.7                 | 3.7          | 16.3          | 18.9            | 7.1   |              |
| J. H. Reynolds             | Greenville  | 1915 |                           | 8.3          | 33.1            | 20.5 | 5.4                  | 4.8          | 13.5          | 29.9            | 3.9   |              |
| Average Percentage of Loss |             |      | 5.4                       | 14.7         | 40.3            | 15.1 | 10.5                 | 7.3          | 9.3           | 29.2            | 8.5   |              |



*Dillon*: In the above table Dillon occurred in seven experiments during three years, and lost on an average of 5.4 per cent. of its plants. In comparing it with its Cook (check), which is very susceptible to wilt, it is noticed that the losses in the check are about twelve times as numerous as in the case of Dillon.

In 1913 Dillon sustained a loss of 7.4 percent at Liverpool, and 15.5 percent at Brundidge.

*Modella*: Modella was tested sixteen times and lost on an average 14.7 percent, its loss covering a range from 1.6 percent in 1914 at Liverpool to 35.4 percent at Brundidge in 1913. It is noted that 1913 was a year during which all varieties suffered badly from wilt and nematodes.

*Cook (check)*: The first check in the above table shows that the loss of cotton plants due to wilt and nematode injuries was severe in every experiment. A wide range of losses from 3 percent at Notasulga in 1915, to 82.5 percent at Brundidge in 1914 is observed. The average loss in the sixteen experiments is 40.3 percent.

*Wood*: This variety closely resembles Dillon in some of its characteristics, and is almost as immune to wilt as Dillon. Its loss ranged from 1.4 percent in 1914 to 27.5 percent in 1913. Its average loss for sixteen experiments was 15.1 percent.

*Covington-Toole*: In comparing this variety with its nearest Cook (check) it is observed that its average loss was only 10.5 percent, while the average loss of the check was 40.3 percent. The loss from wilt was not sufficient to seriously interfere with the stand any year. During the sixteen tests it lost an average of only 10.5 percent.

*Tri-Cook*: This new variety shows that it resisted the attacks of wilt and nematodes remarkably well. In no experiment during the five years did it lose over 19. percent of its plants. Its average loss was only 7.3 percent.

*Cook 307-6*: This variety originated at the Alabama Experiment Station. In the above table it is noted that its greatest loss was in 1913 at Liverpool, when 28.4 percent of its plants died during the growing season. Its range of loss for sixteen experiments varies from no loss to about 28 percent. Its average loss for five years was 9.3 percent.

*Dixie*: This variety occurs in fifteen experiments and sustained an average loss of 8.5 percent.

*Dix-Affi*: This long staple hybrid was planted in two experiments in 1914. In these two experiments it was not subjected to as severe a test as some of the other varieties. It was found that it did not suffer any loss in either of these experiments.

#### AVERAGE LOSSES.

By a study of averages in the above table it is observed that the two check plots lost respectively 40.3 percent and 29.2 percent. Tri-Cook lost the smallest number of plants, the average being only 7.3 percent for the five years, while Cook 307-6 followed very closely with a loss of only 9.3 percent.

It is noted that no variety is entirely immune to root-knot and cotton wilt. In the experiments in which Dillon was included it lost the least number of plants. Of the so-called wilt-resistant varieties, Wood lost the largest number of plants in the sixteen experiments. Enough plants of any of the wilt-resistant varieties withstood the diseases, even under the severest conditions, to make a fairly good stand and to produce crops above the average in value.

#### RELATIVE EARLINESS OF THE WILT-RESISTANT VARIETIES OF COTTON.

A late variety of cotton is not suited to boll weevil conditions. Only the early or medium early varieties seem to give satisfactory yields under heavy weevil infestation. A wilt-resistant variety may be profitable when it is grown on badly infected soil, but may prove a failure after that territory becomes infested with boll weevils.

The Experiment Station is selecting strains from wilt-resistant varieties for earliness and longer fiber, but it has no seed ready for distribution. Addresses of growers of wilt-resistant varieties will be furnished on application to Experiment Station.

Most wilt-resistant varieties tested in these experiments are somewhat late. Below is given a table which shows their relative earliness, as obtained from some of the wilt experiments in different parts of the State.

Table III. — *Relative Earliness of Different Varieties.*

| Varieties             | Location and Percentage of Total Crop Picked |                              |                               |                                 |                               |                                 |                           |
|-----------------------|----------------------------------------------|------------------------------|-------------------------------|---------------------------------|-------------------------------|---------------------------------|---------------------------|
|                       | Loachapoka<br>Sept. 12<br>1912               | Brundidge<br>Sept. 2<br>1914 | Liverpool<br>Sept. 15<br>1914 | Lowndesboro<br>Sept. 22<br>1914 | Notasulga                     |                                 | Auburn<br>Sept. 3<br>1915 |
|                       |                                              |                              |                               |                                 | (McGuire)<br>Sept. 12<br>1914 | (Richardson)<br>Aug. 31<br>1915 |                           |
| Modella -----         | 56.8                                         | 66.2                         | 75.3                          | 85.6                            | 27.3                          | 22.2                            | 16.9                      |
| Cook (check) -----    | 75.0                                         | 73.8                         | 83.9                          | 89.9                            | 47.4                          | 58.3                            |                           |
| Wood -----            | 60.9                                         | 50.5                         | 70.4                          | 84.3                            | 44.0                          | 38.5                            | 27.7                      |
| Covington-Toole ----- | 59.4                                         | 64.4                         | 60.4                          | 87.9                            | 35.9                          | 40.0                            | 24.0                      |
| Tri-Cook -----        | 66.7                                         | 58.0                         | 75.7                          | 82.3                            | 50.0                          | 45.5                            |                           |
| Cook 307-6 -----      | 59.7                                         | 70.5                         | 72.0                          | 86.2                            | 31.5                          | 26.7                            | 23.4                      |
| Dixie -----           | 58.1                                         | 43.2                         | 57.1                          | 81.0                            | 30.8                          | 42.1                            | 25.4                      |
| Dix-Aff -----         |                                              |                              | 77.4                          | 77.4                            |                               |                                 |                           |
| King -----            |                                              |                              |                               |                                 |                               |                                 | 69.2                      |
| Triumph -----         |                                              |                              |                               |                                 |                               |                                 | 35.6                      |
| Cleveland -----       |                                              |                              |                               |                                 |                               |                                 | 44.0                      |

The above table shows that in the 1912 experiment Cook (check) was the earliest and Modella the latest. By September 12th over half the seed cotton of all varieties was picked.

The Brundidge test in 1914 shows that half of all varieties except Dixie was picked by September 2nd. Their earliness as measured by the percentage of total cotton picked by this date ranged from Cook 73.8 percent to Dixie 43.2 percent.

The Liverpool experiment showed that Dix-Afifi was there the earliest of the wilt-resistant varieties and Covington-Toole the latest, the difference between them being about 20 percent.

The experiment at Lowndesboro was picked September 22nd for the first time. The difference between the earliest and latest variety as shown by the first picking is only about 10 percent.

This small difference shows that when the first picking is late, the difference between the earliest and the latest varieties is not wide.

In the 1915 test by Mr. McGuire at Notasulga, the earliest variety was Tri-Cook. In the same year a test conducted by Mr. Richardson in Notasulga and picked August 31st, showed Tri-Cook again the earliest. In the Richardson experiment 27.3 percent of Modella was gathered at the first picking and 50 percent of Tri-Cook.

In the ordinary cotton variety test at Auburn in 1915 the first picking was made September the 3rd. At this time, 16.9 percent of Modella was picked; and 60.2 percent of Wood (this is an early strain of Wood); 35.6 percent of Triumph; 44 percent of Cleveland; and 69.2 percent of King. It must be borne in mind that the last three varieties are not wilt-resistant; they are placed in this table in order that the relative earliness of the wilt-resistant varieties may be compared with some well known early and medium early non-resistant varieties.

The above table shows that among the different wilt-resistant varieties there is not a wide difference in their relative earliness. In comparison with such standard varieties as Triumph, Cook and Cleveland, most of the wilt-resistant kinds must be regarded as somewhat later in maturing.

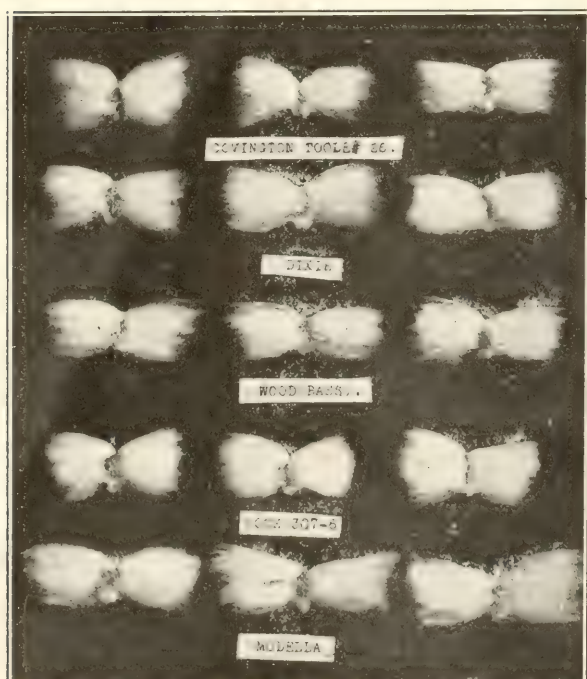
A study of yields of varieties of cotton, as reported







In the centre are the three rows of the original Cook plants tested on severely infested will land at Loachapoka. Notice the resistance of the middle row. The plants on this row constitute the beginning of Cook 307-6, a wilt-resistant strain.



The comparative length of fiber of some of the most important varieties described.

by experiment stations in boll weevil territory, seems to show that some of the medium early varieties often produce a greater money value per acre than the extremely early varieties like King or Simpkins. Certainly where boll weevils are absent or few in numbers, as at Auburn in 1915, certain medium early varieties have surpassed in yield the extremely early varieties.

#### BRIEF DESCRIPTION OF WILT-RESISTANT VARIETIES OF COTTON USED IN EXPERIMENTS. DILLON.

In 1900 some wilt-resistant plants were selected by a representative of the U. S. Department of Agriculture from a badly infected field of Jackson Limbless cotton growing near Dillon, South Carolina. This selection was later named Dillon to distinguish it from Jackson Limbless, its parent. Small quantities of seed of this new variety were widely distributed over the wilt-infected sections of the Cotton Belt, but this variety did not prove very satisfactory because of its cluster habit, lateness in maturing and difficulty in picking. It is the most resistant variety to wilt and nematodes thus far tested by the Alabama Experiment Station.

The Dillon plant grows tall on fertile soil and usually has one, two or three large base limbs. Its fruiting limbs are short and its bolls grow in clusters. The bolls are small, slender, somewhat pointed and difficult to pick. The seed are small and fuzzy. Its fiber is about 7-8 inch long; its percentage of lint is about 37.

#### MODELLA.

This variety originated in Georgia some years ago. It was selected from Excelsior by Mr. A. C. Lewis of the Georgia State Board of Entomology and resembles the old Peterkin variety. The plants are medium size and have many small straight limbs with three or four base limbs. The bolls are medium size and about 80 to 85 of them make a pound of seed cotton. The seed are small and many of them are smooth and black. The percent of lint is about 35; its fiber is from 3-4 to 7-8 inch long. This variety is late and lacks storm resistance.

#### COOK.

Cook variety, which was used as a check in most variety tests, came from the breeding experiment at the Alabama Experiment Station, and represents one of the most productive strains of this variety. The plants are intermediate in type and have two or three base limbs with many long fruiting limbs. The bolls are medium large, open wide and are easily picked. This variety is medium early, but is lacking in storm-proof qualities. The seed are small and very fuzzy; the fiber is short and strong. It turns out at the gin 42 to 43 percent of lint. This variety is very susceptible to wilt and nematodes, and for this reason it was used as a check in the variety tests.

#### WOOD.

The Wood variety was developed by Judge Sam Wood of

Abbeville, Alabama. Its plants are tall and semi-cluster in habit. It is not easy to pick, has medium size bolls, matures late, and has heavy foliage, but it shows considerable wilt-resistance and is productive. The seed are medium size and fuzzy; its fiber is short; it turns out about 35 percent of lint.

A strain of Wood bred by Mr. A. G. Bass, Headland, Alabama, produces a more open type plant and seems a little earlier than ordinary Wood.

#### COVINGTON-TOOLE WILT-RESISTANT.

This variety was developed by Mr. W. F. Covington of Headland, Alabama. It is a selection from the Toole variety, which somewhat resembles Peterkin. The plants are small and have light foliage and are productive. The bolls are ovate, early and easily picked. The seed are small and very fuzzy. The average percentage of lint in seven tests was 39.1; its fiber is short; it shows decided resistance to wilt. This variety is being recommended by the originator for boll weevil conditions.

#### TRI-COOK.

In the fall of 1910, Mr. M. R. Hall of James, Alabama, mixed a small lot of improved Cook and pure Triumph seed cotton and ginned them together. From this mixture he selected the basis of his Tri-Cook variety, which still shows that after five years of selection the type of plant is not yet uniform.

Most plants resemble Cook in type, shape, size of boll, and percentage of lint. The seed are uniform in size, somewhat longer than ordinary Cook. The percentage of lint in a three-year test averages 41.

Tri-Cook ranked well in resistance to root-knot and wilt, as is seen in the table of comparative losses. It ranked second in the average money value of seed and lint per acre in the four years tested.

#### COOK 307-6.

This variety originated at the Alabama Experiment Station. In 1909 three plants that had withstood the wilt were found in the breeding block of the Cook-row-test. They were harvested separately and the seed of each plant was planted on a separate row the next year on badly infested land at Loachapoka. The progeny of one plant showed considerable immunity to wilt, and from this one plant originated the strain of Cook 307-6.

Cook 307-6 resembles the ordinary Cook variety. The plants when grown on fertile land, are inclined to develop a number of vegetative or "wood" limbs. Its bolls are easily picked and about 70 make a pound of seed cotton. They show some storm resistance and seem not so susceptible to boll-rot as the ordinary Cook. Its seed are small and fuzzy; the percentage of lint averages 39.5.

The resistance of Cook 307-6 to wilt and nematode injury is strong. Whether it is early enough for boll weevil conditions remains to be proved.

#### DIXIE.

Dixie was developed by the United States Department of



Agriculture. It belongs to the Peterkin group, and has long basal limbs and long slender fruit limbs. Its bolls are medium size, and it requires about 70 to make a pound of seed cotton. They are easily picked. The seed are small and fuzzy; the percentage of lint to seed is 35; its fiber is about 7-8 an inch long. Dixie is thought to be rather late for boll weevil conditions. It is a resistant variety and produces well under ordinary conditions.

#### DIX-AFIFI.

Dix-Afifi is a hybrid made by Mr. A. C. Lewis, of the Georgia State Board of Entomology, by crossing Dixie on Mit-Afifi. The last named variety is an Egyptain cotton found to be very resistant to nematodes. This hybrid resembles Dixie type of plant. The bolls are medium size, easy to pick, but mature late. The fiber is long and silky; the percentage of lint to seed is about 30.

*This Station has no seed for sale of any of the above varieties, but can furnish, on application, lists of growers of most resistant varieties.*

#### RECOMMENDATIONS FOR CONTROLLING COTTON WILT AND ROOT-KNOT.

The cotton wilt fungus seems to attack only the cotton plant, and fortunately it may be starved out by a judicious rotation of crops.

The choice of crops for a rotation is important where the land is infested with nematodes and wilt. No crop or variety that encourages the multiplication of nematodes or wilt should be introduced into the rotation. A few of the crops that increase the number of nematodes are most varieties of cowpeas, (except Iron and Brabham), sweet potatoes, soybeans, vetches, clovers, sugar cane, melons, and most garden vegetables. Some crops that tend to starve out nematodes and wilt are corn, oats and other grains, grasses, sorghums, velvet beans, peanuts, beggar weed, and Iron and Brabham cowpeas. For infected land the following three-year rotation is suggested:

1st year—Plant corn and between the corn rows or hills plant Iron or Brabham cowpeas. Where early autumn pasture for cattle is desired, velvet beans may be planted with the corn and grazed while green and in time to sow a fall grain crop.

2nd year—Plant oats; after the grain is cut for hay or seed, plant the stubble in Iron or Brabham cowpeas for hay or seed. Follow this with some winter grain for a cover crop.

3rd year—In the spring plow under the cover crop and plant some wilt-resistant variety of cotton.

*Use Wilt-Resistant Varieties:* It is earnestly recommended that only wilt-resistant varieties of cotton be planted on wilt infected land, if such lands must be planted in cotton. The importance of this suggestion is emphasized by a careful comparison of the results of the wilt-resistant and the non-resistant varieties of cotton tabulated in this bulletin.

The farmer may develop a wilt-resistant strain of cotton from his favorite variety if he will carefully follow a few well established principles of plant breeding. However, to breed a good variety of cotton requires a great deal of care and time extending through a number of years. If he is not willing to give the time necessary, he will make more rapid progress by buying pure wilt-resistant seed from some reputable grower, who is engaged in systematic seed improvement.

**ALABAMA**  
**Agricultural Experiment Station**

OF THE

**Alabama Polytechnic Institute**

**AUBURN**

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**Citrus Canker**

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By

**F. A. WOLF, Pathologist**

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\* In co-operation with United States Department of Agriculture.



# CITRUS CANKER

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## INTRODUCTION.

During the past few years considerable attention has been directed to the study of a citrus disease, commonly known as citrus canker. A number of publications dealing with these observations and investigations have been prepared so that a considerable amount of information has been secured relative to the distribution and the appearance of the disease, to the nature of the organisms which cause it, to the agencies concerned in its dissemination and to the difficulties experienced in its control and eradication. Many problems connected with this disease have not yet been investigated, but it is deemed advisable to present at this time the results of the studies thus far conducted.

A report embodying the investigations made by the writer upon citrus canker has been published in the *Journal of Agricultural Research*, (Vol. VI, No. 2.) (1). The present publication contains a rather more brief account of the most important results presented in this report, and in addition contains such information as could be drawn from other papers dealing with citrus canker.

## HISTORICAL.

Citrus canker was introduced into the Gulf States from Japan on nursery stock. It has been found to occur in Japan, the Philippine Islands and parts of Eastern Asia. Whether or not it is indigenous to these countries is not known with certainty, but it is known that it is not of American origin. Specimens were first brought to the writer's attention in February, 1914. The Office of Nursery Inspection of Florida had collected specimens in September, 1912, but did not realize the presence of a new citrus disease within the State until July of the following year. The disease has been collected in all of the Gulf States in the sections adapted to the growth of citrus trees. Within Alabama it is confined principally to Baldwin and Mobile coun-

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(1) Wolf, F. A. Citrus Canker. *Jour. Agr. Research* 6, No. 2, 69-100, Fig. 8, plates VIII-XI, 1916.

ties. A very small percentage of the trees within the state are affected with citrus canker, but when the infectious and virulent nature of the disease is realized it is seen that these few trees are a serious menace to the citrus industry in Alabama. It is for this reason that such energetic efforts are being made to prevent its further introduction and spread and to eradicate the disease already present.

### Hosts.

Citrus canker has been found to occur on many of the species and varieties of citrus. Among them are grape-fruits, King oranges, trifoliate oranges, sweet oranges, naval oranges, mandarines, Satsumas, tangerines, lemons and limes. It has been observed in Louisiana on species of *Fortunella*, to which genus the kumquat oranges belong. Swingle (2) has recorded the presence of canker on kumquats in Japan. It is not equally severe on all of these hosts but grapefruits and trifoliate oranges seem to be much more susceptible than the other varieties. Satsuma oranges appear to be quite resistant. Trees growing in rows adjacent to badly diseased grapefruits have been observed to remain free from disease during an entire season. In other cases Satsuma trees in nursery rows have been observed, all of whose leaves were diseased, some of which leaves had several hundred cankerous areas.

### SYMPTOMS OF THE DISEASE.

Citrus canker manifests itself by the presence of characteristic spots on foliage, twigs, larger branches, and fruits. The diseased areas are usually light brown in color and are raised more or less above the surrounding tissue. The cankers are circular in outline when they occur singly and irregular lesions are formed when several spots fuse. The cankerous tissue consists of a corky mass of cells covered by the lacerated grayish outer membrane of the host. The disease was at first mistaken for scab, but it cannot be confused with scab or other leaf troubles when once one has seen citrus canker in its several stages of development.

Infections on the leaves first appear as small, oily

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(2) U. S. Department of Agriculture, Citrus Canker in the Philippines. U. S. Department of Agriculture Cir. 1, No. 1, plate 8, 1915.



Fig. 1. Citrus canker on branches of grapefruit.

Fig. 2. Citrus trifoliata twigs affected with citrus canker.

Fig. 3. Infection through wounds made by thorn scratches on seedling grapefruit leaves.

PLATE II.



- Fig. 1. Citrus canker spots on grapefruit leaves, natural infection.
- Fig. 2. Spongy, white, prominently projecting cankers on leaf and twig of grapefruit. Plant inoculated with pure culture and continuously kept in a moist atmosphere.
- Fig. 3. Infection resulting from immersion of leaf in suspension containing *Pseudomonas citri*. Cankers occupy nearly the whole of the lower leaf surface.
- Fig. 4. Natural infection on *Citrus trifoliata* leaf.
- Fig. 5. Suspension of *Pseudomonas citri* applied with an atomizer to Satsuma orange leaves, with resultant canker.
- Fig. 6. Old cankers on Satsuma leaf.



or watery dots, most commonly on the lower leaf surface. They are slightly convex and within a few days will have extended entirely through the leaf. The spots gradually increase in size, the convex surface comes to be more and more elevated on one or both leaf surfaces until the outer membranes of the leaf are broken, whereupon the exposed canker tissues become light brown in color (Plate 2, figs. 1, 4 and 6.) An oily border marks the margin of the cankers which come to be surrounded by a yellowish zone. All of the tissues not occupied by the lesions may become yellow, in which case the leaves fall, especially when grapefruits and trifoliate oranges are affected.

Cankers on twigs and larger limbs do not differ materially in appearance from lesions on the leaves. (Plate 1, figs. 1 and 2.) They are larger, project more or less prominently and become variously cracked or fissured. Their presence on the twigs may result in the stunted growth or death of the distal parts. The cankerous areas on the fruits are also similar in appearance to the leaf cankers. Scurfy, elevated spots surrounded by a yellowish zone are formed. When large areas are involved the fruits crack open, thus permitting organisms which cause decay to enter. Affected fruits usually fall, or if they remain on the tree they are rendered very unattractive.

#### CAUSE OF CITRUS CANKER.

The primary cause of citrus canker is a bacterial parasite, *Pseudomonas citri*. Announcement of this fact was first made by Miss Hasse (3) as a result of isolation of the organism from grapefruit and reinoculation with pure cultures upon grapefruit seedlings. The disease had previously been regarded as of fungous origin but the successful artificial inoculations from which this conclusion was drawn were produced by the use of mixed cultures containing *Pseudomonas citri*. The bacterial organism has repeatedly been isolated during the past summer from cankers on grapefruits, Satsumas, trifoliate oranges and lemons. No difficulty has been experienced in effecting cross inoculations from any of these hosts upon either grapefruit,

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(3) Hasse, Clara H. *Pseudomonas citri*, the cause of citrus canker, Jour. Agr. Research 4, No. 1, pp. 97-101, Pls. IV and X, 1915.

pine apple, oranges, Satsumas or seedling trifoliolate oranges. Successful inoculations were made by spraying the trees with a bacterial suspension obtained from pure cultures, plate 2, fig. 5, by immersion of the leaves in such suspensions, plate 2, fig. 3, by transferring the bacteria into the tissues through needle punctures, or by rubbing the leaves between the thumb and fingers after having dipped them in a suspension containing bacteria.

The period of incubation appears to vary, depending on temperature, moisture, and age of the plant tissues. The disease may be evident to the unaided eye three days after inoculation in some cases and ten days may be required in others. The most rapid development of the disease occurs under humid conditions, on young tissues. Mature parts, however, may become diseased. The illustrations, representing natural and artificial inoculations in Miss Hasse's report, differed so materially and the latter were so unlike anything which had ever come under the writer's observations that no explanation of the differences could be made at first. When, however, inoculated plants were kept under bell jars in a saturated atmosphere cankers represented in plate 2, fig. 2, were formed which are regarded as similar to the artificial infections produced by Miss Hasse, plates IX and X.

*Pseudomonas citri* is a yellow, rod-like organism about three or four times as long as broad. It occurs singly or in chains of six or more elements. The organism possesses a lash-like process which enables it to move about in liquids. It grows readily in culture on a variety of artificial media. It is capable of withstanding somewhat higher temperatures than many other bacteria which cause plant diseases. Stevens (4) found that the bacteria can be killed at temperatures ranging from 55-60 degrees C. Tests conducted under other conditions by the writer led to the conclusion that the thermal death point of *Pseudomonas citri* is about 65 degrees C. It is believed to be rather resistant to drying since it retained its vitality for about two months on microscopic slides placed in moist chambers. Stevens (4) found that it did not survive exposure on glass slides for two weeks under laboratory conditions.

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(4) Stevens, H. E. Citrus canker, III, Fla. Agr. Exp. Sta. Bull. 128: p. 3-20; figs. 4, 1915.

He found it to be alive, however, after five weeks on cheese cloth, wetted in a bacterial suspension.



Fig. 1. (a) *Pseudomonas citri* stained with carbol fuchsin, (b) stained with Williams' flagella stain (adapted from Hasse); (c) stained with analine gentian violet.

It has been found that fungi belonging to the genera *Phoma*, *Gloeosporium*, and *Fusarium* are associated with citrus canker. The former alone is notably active in the disintegration of host tissues. This was determined by specific tests for the production of certain enzymes. It was found to be capable of dissolving cellulose, starch, cane sugar and maltose. It is also able to utilize the organic acids of the host as evidenced by a decrease in acid content of tissues on which it is growing. Because of its activity in the disintegration of citrus tissues, of its common association with citrus canker, which fact would help in its identification, its probable introduction to the Gulf States with *Pseudomonas citri*, and the impossibility of assigning it to species already described, it is regarded as an undescribed species and given the name *Phoma socia*.

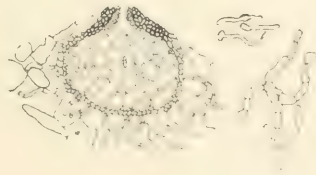


Fig. 2. (a) Pycnidium of *Phoma socia*, (b) Germination of conidia of *Phoma socia*, (c) mycelium in old culture.

## LIFE HISTORY.

So far as is known *Pseudomonas citri* passes its entire life cycle under natural conditions within the host tissues. New infections appear in spring shortly after the new growth has begun. The first appearance in Alabama was on May 11th in 1914 and on May 27th in 1915. Old cankers on leaves and twigs are undoubtedly the source of infection in spring since new leaves formed near such old cankers are especially liable to first become diseased. Infections occur not only on new growth but on old leaves and twigs. Old diseased areas may enlarge by the renewed growth of the organism at the margin of the old cankers. New infections may appear at any time throughout the growing season and have been observed to occur as late as in the month of November. It is not known how long the organism can remain viable under natural conditions on fallen leaves, but it is believed that it can survive the winter. It appears to have perished in the laboratory in packets of leaves kept from September until May in one case, and from March until October in another.

Stevens (4) found that the canker organism was not only alive but also actively growing in inoculated test tubes of soil kept in the laboratory for six months. That it remains alive in the soil is indicated by the appearance of diseased sprouts from the roots of diseased trees which are burned.

Infections occur through natural openings, breathing pores on the leaves and twigs, and through wounds. It was observed in the inoculation experiments that infection appears first on the lower leaf surface, upon which side the stomata occur. From this it was inferred that the bacteria enter the leaf through the stomata. That such is the case was established by a study of leaf sections which were fixed 72 hours after inoculation, infiltrated with paraffin, cut and properly stained. This observation is contrary to that of Stevens (3) in which he states without giving evidence that the organisms are capable of penetrating either surface of the leaf. Infections through natural openings are possible only in the presence of a film of moisture on the host parts. Wounds inflicted on leaves and branches by thorn scratches have been observed to have afforded entrance to the canker organism, plate 1, fig. 3.





Fig. 3. Infection of *Pseudomonas citri* through a stoma or breathing pore with bacteria in substomatal cavity, and adjacent intercellular spaces, seventy two hours after inoculation.

When once the bacteria are within the host they multiply rapidly, effect a passage between the host cells and come to occupy the intercellular spaces. Their presence within the tissues is evidenced in three to five days by oily or watery dots which within another week will have developed into open cankers. At this stage before the exposed cankerous cells have become dry, the greatest danger of spreading the disease exists.

#### EFFECT UPON THE HOST.

The most manifest effect of canker upon the host, as determined by microscopical examination, is the en-

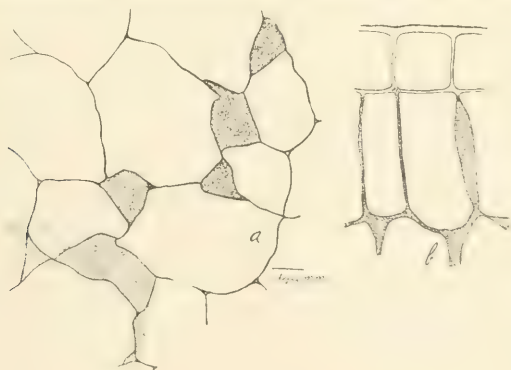


Fig. 4. (a) *Pseudomonas citri* occurring between the cells of the mesophyll tissue and (b) of the palisade parenchyma.

largement of affected cells Little if any cell division in cankerous tissue is believed to occur. The tension re-

sulting from the enlargement of cells causes the rupture of the epidermis and the exposure to desiccation of the cankerous cells. Such cells are only lightly attached to each other as shown in fig. 5, and will separate intact in a drop of water on a slide when spongy cankers, plate 2, fig. 2, are examined. The bacteria are normally found to occur between the cells and not within them, as stated by Hasse.

Several causes operate in bringing about the enlargement and separation of cankerous cells. Among them are (1) the presence of the bacteria between the cells with the consequent passage of materials which are used in the growth of the bacteria, through the host cell walls, (2) the bacteria dissolve the middle lamellae; (3) they dissolve starch and otherwise affect the cell contents so that diseased cells have a greater affinity for water.

Death of diseased cells results in part from drying after the rupture of the epidermis and the cell walls gradually become suberized.

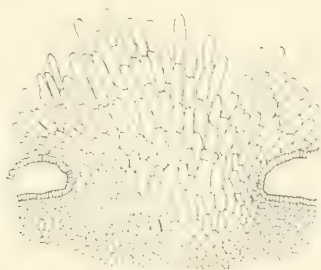


Fig. 5. Spongy canker in outline on rind of grapefruit showing enlargement of cells and indicating the ease with which they may be separated.

A chemical analysis of diseased and of healthy grapefruit leaves by the employment of a refined method of analysis shows that there have been in cankerous tissues profound changes, especially in the carbohydrate and nitrogenous substances. It was also found that there is a decrease in acid content in diseased tissues. An attempt was made to correlate the difference in acidity of grapefruit leaves and Satsuma leaves with the difference in susceptibility of these two species to canker. Satsuma leaves are consistently higher in acid content than grapefruit leaves, but the difference

in total acid content of the two is not regarded as sufficient to account for the difference in susceptibility.



Fig. 6. Cross section of citrus canker on grapefruit leaf showing enlargement of cells of mesophyll and collapse of exposed cells.

#### SPREAD OF CITRUS CANCER.

Rain and dew are probably to be regarded as very important factors in carrying the disease to unaffected parts of trees in which the disease is already present. Man himself is a very important agent in effecting the spread of canker from diseased trees to nearby healthy ones. The bacteria may be present in drops of water or in a film of moisture on the affected trees, especially if newly formed cankers occur on these diseased trees. In the cultivation and care of the groves man may come in contact with these infected trees and carry the bacteria to healthy ones. The spread of canker to two groves which have come under observation was very probably effected by the human agency. Sterling (5) reports transmission of the disease through handling diseased leaves prior to touching healthy ones. Certain birds and insects may also transfer the organism from diseased to healthy parts.

#### CONTROL.

Efforts toward control have been directed along three lines: exclusion, protection and eradication.

The further introduction of the disease into the United States from foreign countries and localities has

(5) Berger, E. W., Stevens, H. E., and Sterling, Frank. Citrus canker II. Fla. Agr. Exp. Sta. Bull 124, 27-53, figs. 6-14, 1914.

been prevented by Federal quarantine. The several states themselves have passed regulatory measures to prevent the further spread of canker within the states and from any one of them to any other of them.

The use of fungicides and disinfectants indicates that there is little to be hoped for in their use for protection against citrus canker. Field tests have been made with Bordeaux mixture, ammoniacal copper carbonate, soluble sulfur, Bordeaux to which bichloride of mercury, 12 tablets to three gallons, had been added, Bordeaux containing formaldehyde, 1-100, and Pyrox. Even when all visible signs of the disease are removed from the trees prior to the application of the fungicides their use does not prevent the reappearance of the disease on these trees.

The only method known of checking citrus canker is the complete destruction of all infected trees. Eradication by this procedure seems possible, but only when the work has been thoroughly done, with the observance of the strictest sanitary precautions.

The early efforts toward the eradication of citrus canker were confined to the removal of diseased parts in case the trees were only slightly diseased. When they were badly diseased the trees were severely pruned even though this necessitated the removal of all or nearly all of the branches. Trees thus treated were then sprayed thoroughly with Bordeaux mixture. After a few months trial it was found that the trees were still diseased. Further than this, the adjacent trees had become diseased, although they were apparently healthy when the pruning was done. As a result of this it was decided that only the complete destruction of affected trees as they stand in groves or nurseries would be effective. The eradication campaign with its concerted, heroic effort to stamp out citrus canker from the Gulf States is the outgrowth of this decision.



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**JUNE, 1916**

TECHNICAL BULLETIN No. 1

**ALABAMA**  
**Agricultural Experiment Station**

OF THE

**Alabama Polytechnic Institute**

**AUBURN**

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**The Effects of Certain Organic Compounds  
On Plant Growth**

**Coumarin, Vanillin, Pyridine, Quinoline,  
Dihydroxystearic Acid, Pyrogallol, Etc.**

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By

**M. J. FUNCHESS, Associate Agriculturist**

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1916  
Post Publishing Company  
Opelika, Ala.

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\* In co-operation with United States Department of Agriculture.

# THE EFFECTS OF CERTAIN ORGANIC COMPOUNDS ON PLANT GROWTH

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By

M. J. FUNCHESS, Associate Agriculturist.

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## INTRODUCTION.

The causes of fertility or infertility of soils are usually explained by soil chemists and physicists in terms of plant food, or physical condition of soils. Unproductive soils are either deficient in some element, or elements, needed for plant growth, or they are in a bad physical condition, according to these old and rather generally accepted views. Such unfavorable conditions may be remedied by the application of manures and fertilizers, thereby supplying the deficient elements; or through the amelioration of the soil by the use of lime, by the addition of organic matter, and by thorough pulverization with tillage implements.

In comparatively recent years, a quite different view of the causes of infertility has been developed in the United States by the Bureau of Soils of the United States Department of Agriculture. According to this very advanced theory, infertility is frequently due to the presence in soils of substances which are injurious to plants, rather than to deficiencies of plant food. These harmful substances are root excretions, or are due to the products resulting from organic decomposition within the soil. To restore such soils to fertility, the injurious compounds must in some way be removed or rendered harmless. In support of this position, quite a large amount of experimental work has been reported.\* The bulk of such experimental evidence, however, has been obtained from solution cultures, using wheat seedlings as the plant indicator, the plants being allowed to grow for only short periods. The methods used by the Bureau of Soils are fully described in several of its bulletins.

## OBJECT OF THE EXPERIMENTS.

The work herein reported was undertaken in order to determine, if possible, whether the results obtained

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\* See especially bulletins No. 23, 28, 36, 40, 47, 53, 70, 77 and 87, of the Bur. of Soils, U. S. Dept. of Agr.

with soil cultures would parallel the results obtained with solution cultures. It is well known that for many organic substances, the powers of absorption and adsorption possessed by soil are high; it is also well known that in unsterilized soil numerous complex chemical and biochemical reactions may occur, while such reactions in solutions, are largely absent and occur slowly when at all. It seemed logical, therefore, to expect differences between the results obtained by the two methods, because of the greater absorptive, chemical, and biochemical action of soil.

In order to make such comparisons, the writer planned a series of experiments in the fall of 1913, and had the experiments conducted by a number of students, who used the data so obtained as a thesis for the B. S. degree. The results so obtained are incorporated in this publication, together with data subsequently obtained by the writer. The data obtained from the solution culture work were parallel with those reported by the Bureau of Soils, and were discontinued after the first set of trials was completed; however, the results of the soil culture experiments did not accord with those of the solution cultures. For this reason all of our later work was done with soil as the medium in which the plants were grown.

#### THE METHODS USED.

All of the data given were obtained from experiments conducted in the greenhouse, the plants being grown in either 2-gallon or 4-gallon pots. In all cases where the 2-gallon pots were used, each pot contained 20 pounds of air dry, screened soil; while the 4-gallon pots contained 40 pounds of air dry, screened soil. The special treatments, as well as the fertilizer treatments, were applied as follows: about an inch of soil was removed from the pot to be treated, and the materials added; then the soil in the pots was well stirred so as to thoroughly mix the added materials with the upper half of the soil in the pots. After this mixing, the soil that had been removed was returned to the pot. The special substances or compounds were usually added at the rates of 100, 250, 500, and 1000 parts per million of dry soil. In the later work, the smaller ratios were omitted, since the apparent effects of the small quantities were rather slight.

Based on the 40 pounds of soil per large pot, 18 grams



of material is approximately equal to 1000 parts per million of soil, 9 grams, to 500 parts, and so on. For the small pots containing only 20 pounds of soil, half of these quantities were used so as to get the same ratios that were used for the large pots. In all cases, the crops were planted on the same day that the various treatments were applied. From time to time, the pots were watered with tap water so as to maintain a sufficient supply; but no attempt was made to maintain a definite weight in the several pots.

#### SPECIAL CHEMICALS USED.

All of the special reagents used in this work were prepared by E. Merck & Co., with the exception of pyridine and dihydroxystearic acid, which were Kahlbaum products. The required amounts of all compounds were weighed out on chemical balances, for the experiments conducted the first year; however, only the solid compounds were weighed, for the work of the second year, because of the difficulty involved in weighing exact quantities of liquids. The liquids were measured, rather than weighed, one cubic centimeter being assumed to weigh one gram; this assumption is not exact, though it is sufficiently close for the purposes of the work in hand.

#### SOILS TESTED.

Four different soils were used in the experiments which were begun in 1913. The heaviest of the four, classed as Cecil clay by the Bureau of Soils, is a rather heavy, sticky, red clay. The area from which our supply came had not been in cultivation for a year or two, and had grown up in lespedeza, weeds, and a few small bushes. The lightest and poorest, classed as Cecil sand, is a very poor, open, dry sandy soil. Our supply came from a field which had grown a very poor crop of corn during the summer of 1913. Two samples of Norfolk sandy loam were used; one was taken from a rather poor field about a mile south of the Experiment Station farm, while the other was obtained from the most productive part of the Experiment Station farm. The soil samples were spread in a thin layer on a concrete floor and stirred frequently until they became well dried. After the drying, samples of 20 pounds, or 40 pounds, as the size of the pot required, were weighed

into the pots, and the pots transferred to the greenhouse.

For the work which began in the fall of 1914, a fresh sample of soil was collected from the same field from which the poor sample of Norfolk sandy loam had been taken the previous year.

#### CROPS GROWN.

Oats were grown on all pots during the fall and winter of each of the two years when these experiments were in progress. The oats were allowed to grow until quite an advanced stage was reached, when the crop was harvested and weighed. After the oat crop was taken off, corn was planted on all pots in the first year of the work; while the corn or peas followed the oats of the second year. The corn was grown until tassels were showing, or until the corn was well advanced. A good idea of the stage of growth reached in each case can be had from the photographs. All crop weights given are in grams. For further details, see the tables and discussion accompanying the tables.

#### RESULTS OF POT EXPERIMENTS WITH CULLERS FIELD SOIL.

In table I the results obtained on Cullers Field soil are given. The plants were grown in 2-gallon stoneware pots, each pot containing 20 pounds of soil. Oats were planted in the fall of 1913, and harvested in the early spring of 1914, just after the plants had fully headed out. After the oat crop was harvested, 9 grams of acid phosphate were added to each pot which had not received phosphate treatment for the oats, and each planted to corn. The corn crop was harvested just as the most forward plants were beginning to tassel. The air dry weights of the two crops, and the combined weights are given in the table. In the last column of the table, the results are shown in a relative way, the unfertilized yield being taken as 100.

*Table 1. Effect of fertilizers, lime, carbon black, pyrogallol, coumarin, vanillin, pyridine and quinoline on crop yields in Cullers Field soil. Crops grown in 2-gallon pots in the greenhouse, 1913-1914.*

| KIND OF TREATMENT                      | Grams | Weight of air-dry oats, first crop | Weight of air-dry corn, second crop | Combined weight of two crops | Relative yield, unfertilized yield 100 |
|----------------------------------------|-------|------------------------------------|-------------------------------------|------------------------------|----------------------------------------|
|                                        | gr'ms | gr'ms                              | gr'ms                               | gr'ms                        | gr'ms                                  |
| Check, no treatment -----              |       | 7.6                                | 8.3                                 | 15.9                         | 100                                    |
| Nitrate of Soda -----                  | 9.0   | 30.8                               | 18.3                                | 49.1                         | 308                                    |
| Kainit -----                           | 9.9   | 16.0                               | 10.4                                | 26.4                         | 172                                    |
| Acid Phosphate -----                   | 9.0   | 41.9                               | 11.8                                | 53.7                         | 337                                    |
| Nitrate, Kainit, Phosphate, each ----- | 9.0   | 79.5                               | 21.3                                | 100.0                        | 634                                    |
| Calcium Carbonate -----                | 9.0   | 7.6                                | 11.3                                | 18.9                         | 119                                    |
| Carbon Black -----                     | 9.0   | 5.6                                | 9.0                                 | 14.6                         | 91                                     |
| Pyrogallol -----                       | 9.0   | 13.0                               | 8.6                                 | 21.6                         | 135                                    |
| Pyrogallol -----                       | 4.5   | 6.4                                | 9.6                                 | 16.0                         | 100                                    |
| Pyrogallol -----                       | 2.25  | 5.7                                | 10.5                                | 16.2                         | 102                                    |
| Pyrogallol -----                       | 0.9   | 17.2                               | 8.7                                 | 25.9                         | 162                                    |
| Coumarin -----                         | 9.0   | 4.8                                | 12.2                                | 17.0                         | 107                                    |
| Coumarin -----                         | 4.5   | 6.2                                | lost                                | ?                            | ?                                      |
| Coumarin -----                         | 2.25  | 22.9                               | 12.7                                | 35.6                         | 224                                    |
| Coumarin -----                         | 0.9   | 10.0                               | 10.2                                | 20.2                         | 127                                    |
| Vanillin -----                         | 9.0   | 4.8                                | 12.0                                | 16.8                         | 105                                    |
| Vanillin -----                         | 4.5   | 5.7                                | 8.5                                 | 14.2                         | 89                                     |
| Vanillin -----                         | 2.25  | 6.7                                | lost                                | ?                            | ?                                      |
| Vanillin -----                         | 0.9   | 6.9                                | 11.7                                | 18.6                         | 117                                    |
| Pyridine -----                         | 9.0   | 25.7                               | 17.1                                | 42.8                         | 269                                    |
| Pyridine -----                         | 4.5   | 30.6                               | 13.0                                | 43.6                         | 274                                    |
| Pyridine -----                         | 2.25  | 26.4                               | 9.9                                 | 36.3                         | 228                                    |
| Pyridine -----                         | 0.9   | 30.5                               | 12.3                                | 42.8                         | 269                                    |
| Quinoline -----                        | 9.0   | 27.7                               | 25.6                                | 63.3                         | 335                                    |
| Quinoline -----                        | 4.5   | 30.8                               | 11.2                                | 41.0                         | 258                                    |
| Quinoline -----                        | 2.25  | 5.8                                | 11.7                                | 17.5                         | 110                                    |
| Quinoline -----                        | 0.9   | 11.5                               | 12.6                                | 24.1                         | 151                                    |

Under the conditions of these tests, this Norfolk sandy loam soil responded well to nitrate of soda and acid phosphate, when oats was the crop grown; kainit was much less beneficial, while lime was not effective. The crop of corn following the oats was most benefited by the residue from the nitrate and from the complete fertilizer. The natural productive power of this soil is very low, as shown by the yields of the two crops.

It is interesting to note that the application of such materials as lime, carbon black, and pyrogallol have been of little or no benefit to this soil; it is also very interesting that coumarin and vanillin, both of which

are very toxic to plants in water cultures, have not been more highly injurious to corn and oats grown in soil. It is true that the oat crop following immediately after the application of these compounds has been somewhat injured; but it is also true that the corn crop following several months after the treatments, has not only not been injured, but has, apparently, been slightly improved. The combined weight of the two crops from the several pots treated with vanillin and coumarin is in most cases greater than the combined weight of the crops from the untreated pots.

The results from the use of pyridine and quinoline, both of which are nitrogenous compounds, were entirely unexpected. In water cultures, these substances are almost always toxic to plants; but in soil cultures, both of the compounds have considerably increased the crop yields. The combined crops obtained from pyridine and the quinoline treated pots are very much larger than those obtained from the checks; indeed, nitrate of soda has been but little more effective than have these two organic "toxins."

#### RESULTS OF POT EXPERIMENTS WITH CECIL CLAY SOIL.

Table II shows the results obtained from Cecil clay soil. This test was conducted in 2-gallon pots, each pot containing 20 pounds of the screened soil. The first crop grown was oats, which crop was planted in the fall of 1913. When the oats were fully headed out the following spring, the crop was harvested, allowed to become thoroughly air dry, and weighed. All pots which had not received acid phosphate in the treatments given the oat crop, were given 9 grams of acid phosphate and planted to corn, in the spring of 1914. The corn was harvested when the largest plants were beginning to show tassels, and weighed, after it had become thoroughly air dry. The table of results follows:



*Table II. Effect of fertilizers, lime, carbon black, pyrogallol and coumarin on crop yields in Cecil clay soil. Crops grown in the greenhouse, 1913-1914.*

| KIND OF TREATMENT                  | Amount of treatment, grams | Grams of air-dry oats. First crop | Grams of air-dry corn. Second crop | Combined weight of two crops | Relative yields, unfertilized yield 100% |
|------------------------------------|----------------------------|-----------------------------------|------------------------------------|------------------------------|------------------------------------------|
| Check, no treatment                |                            | 16.5                              | 8.5                                | 25.0                         | 100                                      |
| Nitrate of Soda                    | 9.0                        | 10.6                              | 10.8                               | 21.4                         | 85                                       |
| Kainit                             | 9.0                        | 8.5                               | 7.6                                | 16.1                         | 64                                       |
| Acid Phosphate                     | 9.0                        | 44.7                              | 10.2                               | 54.9                         | 219                                      |
| Nitrate, Acid Phosphate and Kainit | 9.0                        | 124.3                             | 8.6                                | 132.9                        | 531                                      |
| Calcium Carbonate                  | 9.0                        | 7.0                               | 9.1                                | 16.1                         | 64                                       |
| Carbon Black                       | 9.0                        | 12.4                              | 10.5                               | 22.9                         | 93                                       |
| Pyrogallol                         | 9.0                        | 7.7                               | 8.9                                | 16.6                         | 66                                       |
| Pyrogallol                         | 4.5                        | 9.9                               | 12.9                               | 22.8                         | 91                                       |
| Pyrogallol                         | 2.25                       | 6.4                               | 9.8                                | 16.2                         | 64                                       |
| Pyrogallol                         | 0.9                        | 6.1                               | 10.2                               | 16.3                         | 65                                       |
| Coumarin                           | 9.0                        | 5.6                               | 9.6                                | 15.2                         | 61                                       |
| Coumarin                           | 4.5                        | 5.6                               | 9.4                                | 15.0                         | 60                                       |
| Coumarin                           | 2.25                       | 11.5                              | 9.5                                | 21.0                         | 84                                       |

The results obtained in this test are rather peculiar, and are difficult to explain. None of the treatments, excepting the acid phosphate and the complete fertilizer, was beneficial to oats. The differences in the corn yields from the several treatments are not great enough to warrant any conclusions.

One striking point brought out in this test was the very marked effect of phosphate on the growth and stooling of oats during the first few weeks of growth of the plants. Had the test been terminated at the end of the first month, the results obtained, using air dry weight as a criterion, would have shown that phosphate was even more beneficial than was the complete fertilizer. The plants on the phosphate-treated pot made a very vigorous early growth, and the amount of stooling was greatly in excess of that on any other pot. After about the first month, however, the plants began to turn yellow and show dead leaves at the bottom. On the other hand, the plants on the pot with complete fertilizer continued to grow rapidly and never lost color. The great need of phosphate is indicated by the

yield obtained from the pot treated with nitrate of soda alone.

Attention is called to the fact that kainit, lime, carbon black, pyrogallol and coumarin were apparently injurious to oats, and without effect on corn. Neither crop was increased by the addition of such corrective agents as carbon black and pyrogallol. The evidence seems to show that this soil is poor because of a specific lack of available plant nutrients, rather than because of the presence of compounds toxic to the crops grown.

#### RESULTS OF POT EXPERIMENTS IN NORFOLK SANDY LOAM FROM COLLEGE FARM.

The yields obtained from soil collected from the Experiment Station farm are reported in table III. In this test, the plants were grown in 4-gallon pots, each pot containing 40 pounds of the screened soil. A crop of oats was grown during the fall and winter months, and was harvested when the plants were in full head. The pots which had not received phosphate in the treatment given the oats were then treated with a full dose of phosphate, i. e., 18 grams. Corn was planted in all pots and allowed to grow until tassels were beginning to show on most plants, when the crop was harvested, dried and weighed.

*Table III. Effect of fertilizers, lime, carbon black, pyrogallol, and pyridine on crop yields in College Farm soil. Crops grown in 4-gallon pots in the greenhouse, 1913-1914.*

| KIND OF TREATMENT                      | Amount of treatment, grams | Grams of air-dry oats, First crop | Grams of air-dry corn, Second crop | Combined weight of two crops | Relative yield, unfertilized yield 100 |
|----------------------------------------|----------------------------|-----------------------------------|------------------------------------|------------------------------|----------------------------------------|
| Check, no treatment -----              |                            | 30.7                              | 19.1                               | 49.8                         | 100                                    |
| Nitrate of Soda -----                  | 18.0                       | 191.0                             | 16.9                               | 207.9                        | 418                                    |
| Acid Phosphate -----                   | 18.0                       | 156.5                             | 15.6                               | 172.1                        | 345                                    |
| Kainit -----                           | 18.0                       | 27.1                              | 24.6                               | 81.7                         | 164                                    |
| Nitrate, Phosphate, Kainit, each ----- | 18.0                       | 120.0                             | 19.4                               | 139.4                        | 280                                    |
| Calcium Carbonate -----                | 18.0                       | 38.9                              | 21.1                               | 60.0                         | 120                                    |
| Carbon Black -----                     | 18.0                       | 41.0                              | 16.9                               | 57.9                         | 116                                    |
| Pyrogallol -----                       | 18.0                       | 19.7                              | 19.1                               | 38.8                         | 78                                     |
| Pyrogallol -----                       | 9.0                        | 31.8                              | 16.8                               | 48.6                         | 99                                     |
| Pyrogallol -----                       | 4.5                        | 48.5                              | 18.6                               | 67.1                         | 134                                    |
| Pyrogallol -----                       | 1.8                        | 49.0                              | 19.3                               | 68.3                         | 136                                    |
| Pyridine -----                         | 18.0                       | 138.9                             | 19.3                               | 158.2                        | 317                                    |
| Pyridine -----                         | 9.0                        | 141.8                             | 14.2                               | 156.0                        | 313                                    |
| Pyridine -----                         | 4.5                        | 106.0                             | 20.2                               | 126.2                        | 255                                    |
| Pyridine -----                         | 1.9                        | 52.7                              | 19.5                               | 72.2                         | 145                                    |

Nitrogen and phosphorus were both very effective on the oat crop, while kainit and lime were only slightly beneficial. For some unaccountable reason, the plants on the pot with complete fertilizer made a poor growth from the beginning, and it is possible that some error was made in applying the treatments, but no source of error could be discovered. In two cases, light applications of pyrogallol appeared to have slightly benefitted the oats, but there was no corresponding benefit to corn; and it is doubtful whether this slight increase in the oat crop is due to any action of the pyrogallol. It is probable that small differences are due to slight inequalities in the fertility of the potted soil, rather than to any helpful action of the material added.

A most interesting result of the work with this soil is that pyridine is nearly as effective in increasing the oat crop as is nitrate of soda. Reference to the last column of the table shows at a glance that this compound very greatly increased the crop, rather than causing any injury, as would have been expected from water cultures.

None of the various treatments affected the corn crop following the oats.

#### RESULTS OF POT EXPERIMENTS ON CECIL SAND.

The Cecil sand used in the experiments of 1913-1914 was the poorest of the four soils used in the work. Apparently, this soil was so deficient in nitrogen, phosphorus and potash that only the complete fertilized pot made a very satisfactory growth. Carbon black seemed to be of some benefit to the oats, but did not increase the crop of corn following. Nor was pyrogallol of benefit to either of the crops. On the other hand, instead of being harmful, quinoline more than doubled the yield of the crops, where the larger quantities of the compound were used; and, as was the case with pyridine, was nearly as effective as nitrate of soda.

In the following table will be found the results obtained with Cecil sand:

*Table IV. Effect of fertilizers, lime, carbon black, pyrogallol and quinoline on crop yields in Cecil sand. Crops grown in 4-gallon pots in the greenhouse, 1913-1914.*

| KIND OF TREATMENT                | Amount of treatment, grams | Grams of air-dry oats. First crop | Grams of air-dry corn. Second crop | Combined weight of two crops | Relative yield, unfertilized yield 100 % |
|----------------------------------|----------------------------|-----------------------------------|------------------------------------|------------------------------|------------------------------------------|
| Check, no treatment              |                            | 16.5                              | 13.5                               | 30.0                         | 100                                      |
| Nitrate of Soda                  | 18.0                       | 54.6                              | 28.4                               | 83.0                         | 276                                      |
| Kainit                           | 18.0                       | 33.9                              | 13.6                               | 47.5                         | 158                                      |
| Acid Phosphate                   | 18.0                       | 89.2                              | 7.2                                | 96.4                         | 321                                      |
| Nitrate, Phosphate, Kainit, each | 18.0                       | 190.9                             | 46.1                               | 237.0                        | 790                                      |
| Calcium Carbonate                | 18.0                       | 24.7                              | 11.1                               | 35.8                         | 119                                      |
| Carbon Black                     | 18.0                       | 35.6                              | 11.2                               | 46.8                         | 156                                      |
| Pyrogallol                       | 18.0                       | 16.5                              | 11.2                               | 27.7                         | 92                                       |
| Pyrogallol                       | 9.0                        | 20.8                              | 11.7                               | 32.5                         | 108                                      |
| Pyrogallol                       | 4.5                        | 16.2                              | 12.3                               | 28.5                         | 95                                       |
| Pyrogallol                       | 1.8                        | 22.6                              | 11.1                               | 33.7                         | 112                                      |
| Quinoline                        | 18.0                       | 31.4                              | 44.5                               | 75.9                         | 253                                      |
| Quinoline                        | 9.0                        | 60.4                              | 23.4                               | 83.8                         | 279                                      |
| Quinoline                        | 4.5                        | 49.5                              | 10.0                               | 59.5                         | 198                                      |
| Quinoline                        | 1.8                        | 36.2                              | 10.5                               | 46.7                         | 156                                      |

The oat crop was harvested when the plants were out in full head, allowed to become thoroughly air dry, and was then weighed.

Eighteen grams of phosphate were added to each pot



which had not received phosphate in the treatments given the oats, and all were then planted to corn.

The corn crop grew until the largest plants were beginning to show tassels, when the corn was cut, air dried in the greenhouse, and weighed.

#### CONCLUSIONS FROM THE FIRST YEAR'S WORK.

The following conclusions seem to be justified, based on the experiments conducted during the fall, winter and spring of 1913-1914:

1. That the poor soils experimented upon were not benefited by the application of such substances as carbon black, pyrogallol, or calcium carbonate.

2. That coumarin and vanillin, when added to soil, were toxic to plants only when used in large amounts, and when these large amounts were added to the soil at time of seeding.

3. That nitrogenous compounds like pyridine and quinoline were beneficial, rather than harmful, as has been found to be true by means of water cultures.

4. That four or five months after the addition of coumarin and vanillin to a soil, no toxic effect on corn was apparent.

5. That plants must be grown for longer periods than two or three weeks, in fertility work, if true conclusions are to be reached.

6. That these conclusions were borne out in all of the four widely different types of soil used in this work.

#### EXPERIMENTS CONDUCTED IN 1914-1915.

One of the experiments conducted during the second year was designed to show whether or not repeated applications of toxic compounds to soils would finally result in marked injury to plant growth. To study this point a number of pots used in the work of the first year were carried into the work of the second year with the same treatments, and the same crops as were used in the beginning of the work. The data so obtained are given in Table V. All of the data concerning these pots during the first year, may be found by reference to Table I.

During the summer of 1914, the pots were left dry and undisturbed in the greenhouse. In the fall of this year, these pots were treated as shown in the first column of

Table V, and planted to oats. After the oat harvest, each pot was treated as shown in the third column, and planted to corn. In the fourth column, the combined crop weights are given; and in the last column will be found the relative combined yields, based on the untreated pots as 100.

*Table V. Effect of repeated treatments with fertilizers, pyridine, quinoline, vanillin, pyrogallol and coumarin on crop yields in Cul-lers Field soil. Crops grown in 2-gallon pots in the green house, 1914-1915.*

| KIND AND AMOUNT OF<br>TREATMENT TO OATS | Green weight of<br>oats grams | Kind and amt.<br>of treatment to<br>corn | Green weight of<br>corn grams | Combined wt.<br>of two crops | Relative yields<br>unfertilized,<br>yield 100 % |
|-----------------------------------------|-------------------------------|------------------------------------------|-------------------------------|------------------------------|-------------------------------------------------|
| Check—no treatment .....                | 14                            |                                          | 19                            | 33                           | 100                                             |
| Kainit, 4.5 grams .....                 | 19                            | K.                                       | 26                            | 45                           | 136                                             |
| Nitrate of soda, 4.5 grams .....        | 110                           | N.                                       | 43                            | 153                          | 463                                             |
| Kainit and phosphate .....              | 18                            | K. & P.                                  | 27                            | 45                           | 136                                             |
| K., P. & N. ....                        | 234                           | K., P. & N.                              | 289                           | 523                          | 1585                                            |
| Pyridine, 4.5 cc .....                  | 43                            | K. & P.                                  | 89                            | 132                          | 400                                             |
| Pyridine, 9.0 cc .....                  | 67                            | K. & P.                                  | 228                           | 295                          | 894                                             |
| Quinoline, 4.5 cc .....                 | 36                            | K. & P.                                  | 121                           | 156                          | 472                                             |
| Quinoline, 9.0 cc .....                 | 61                            | K. & P.                                  | 183                           | 244                          | 739                                             |
| Vanillin, 4.5 grams .....               | 9                             | K. & P.                                  | 40                            | 49                           | 148                                             |
| Vanillin, 9.0 grams .....               | 8                             | K. & P.                                  | 35                            | 43                           | 130                                             |
| Pyrogallol, 4.5 grams .....             | 14                            | K. & P.                                  | 27                            | 41                           | 124                                             |
| Pyrogallol, 9.0 grams .....             | 12                            | K. & P.                                  | 28                            | 40                           | 121                                             |
| Coumarin, 4.5 grams .....               | 8                             | K. & P.                                  | 38                            | 46                           | 139                                             |

\* "K" means 4.5 grams of kainit; "N" means 4.5. grams of nitrate; "P" means 4.5 grams of phosphate.

The repeated application of toxic compounds like vanillin and coumarin proved to be more injurious for oats than was the first application; on the other hand, the repeated application of pyrogallol had practically no effect on the yields of either of the two crops. The oat crop followed immediately after the various treatments had been applied to the pots; and the yields of this crop seem to have been reduced somewhat by the presence of vanillin and coumarin. But the corn crop, which followed several months after the addition of these toxic compounds, was apparently benefited to a slight degree by their presence, or rather, by

their addition to the soil at the time of planting the previous crop. A study of the combined yields obtained shows that the smallest total yield was obtained from the untreated pot; on this basis of comparison, the presence of pyrogallol, vanillin and coumarin influenced the crop yields but little. It does not appear from this work that either vanillin or coumarin is injurious to crops unless applied in very large quantities just before the crop is planted. Further, it does not appear that pyrogallol has any beneficial effect on the yields obtained under the conditions of these experiments.

The results obtained from the use of the nitrogenous compounds, pyridine and quinoline, are in strict accord with those obtained the first year. Instead of being harmful, as they are in water cultures, these substances have proved to be beneficial; and the benefit is roughly proportional to the amounts of the materials applied. The crop of oats obtained from the pots which had received 9 cc of these compounds was about four times as great as that from the untreated pot. When potassium and phosphorus were added to the pyridine and quinoline treated pots, the yields were roughly ten times as great as that of the check, and from six to eight times as great as that from the pot receiving potassium and phosphorus only. There is no evidence from this experiment that there is any cumulative injury resulting from the addition of such compounds to the soil in which plants are grown; as a matter of fact, there appears to be slightly less injury from the second dose of vanillin and coumarin than there was from the first dose.

Are fertilizers valuable because they carry plant food, or are they effective because they serve as an antidote or to decompose toxic compounds? Is there a plentiful supply of available phosphorus and potassium in soils at all times? A little light is shed on these questions by the data in the above table. For example, compare the untreated pot yields with those with the pot treated with kainit and phosphate; by this comparison, phosphorus and potassium are not much needed. But if a comparison is made between the pot with nitrate and with complete fertilized pot, it will be seen that the effect of the phosphorus and potassium has been very great. By this method of

comparison, two values of quite different magnitude may be obtained for the phosphate-potassium combination. In the same way, two very different values may be obtained for the nitrate of soda. The difference between the total yield of the untreated pot and the nitrate pot is 120 grams; but the difference between the phosphate-kainit pot and the complete fertilized pot is 478 grams. Apparently this soil is inadequately supplied with either nitrogen or the mineral nutrients, if large crop yields are to be considered. On the other hand, if these fertilizers owe their effectiveness to their action on toxic compounds existing in the soil, then it takes a complete fertilizer to get the desired results on this soil.

The deficiency of mineral elements may be shown by another set of comparisons. Nitrate of soda alone is much more effective than either pyridine or quinoline alone, when used for oats; but when the mineral elements are added to pyridine and quinoline, while the nitrate is repeated, then for the second crop the residues from these two nitrogenous toxins become more effective than nitrate, in promoting the growth of a crop of corn following the oats. In other words, one application of pyridine and quinoline, along with the minerals, is more effective than is two applications of nitrate of soda.

In the light of these comparisons, and in the light of the fact that neither lime, carbon black, nor pyrogallol increased the productiveness of this soil, the conclusion seems justified that *this poor soil* is unproductive, not so much because of the presence in it of toxic compounds, but because of an *actual deficiency of available plant foods*.

Comparisons similar to those above may be made from most of the data presented in the other tables in this publication.



## RESULTS OF POT TESTS CONDUCTED ON NORFOLK SANDY LOAM SOIL FROM "CULLERS FIELD."

In the experiments conducted during the fall and winter of 1913-1914, the various materials used were applied alone to the four soils used in the work. As this early work developed, it became clear that a complete fertilizer was needed to obtain large yields, no matter what type of soil was being studied. Lime, kainit, and acid phosphate, either singly or in combination, increased the yields of oats and corn very little. But when nitrate of soda was added to the mineral fertilizers, abundant growths were easily obtained. It also developed that pyridine and quinoline were not only not toxic, but were beneficial when applied to either oats or corn; and that the benefit was greater when used in connection with phosphate and potash than when used alone. Therefore, the bulk of the work done the second year aimed to show the effect on plant growth of the various compounds at hand, when used alone and also in connection with various fertilizer combinations. A lack of greenhouse space and of pots made it necessary for us to confine the study to one soil. The soil chosen was the poorer grade of Norfolk sandy loam designated "Cullers Field" soil in the foregoing pages. The fresh sample used was collected, dried and potted in the manner already described.

*Table VI. Effect of fertilizers, lime, coumarin, vanillin, pyrogallol and carbon black on crop yields in Cullers Field soil. Crops grown in 2-gallon pots in the greenhouse, 1914-1915.*

| SPECIAL TREATMENT         | Fertilizer elements applied | Green weight of oats, grams | Green weight of corn, grams | Combined weight of crops | Relative yields complete fertilized yields 100 % | Relative yields unfertilized, yields 100 % |
|---------------------------|-----------------------------|-----------------------------|-----------------------------|--------------------------|--------------------------------------------------|--------------------------------------------|
| Check—no treatment        |                             | 12                          | 16                          | 28                       |                                                  | 100                                        |
| None                      | K *                         | 26                          |                             |                          |                                                  |                                            |
| None                      | K. & P.                     | 16                          |                             |                          |                                                  |                                            |
| Cal. carbonate, 9.0 grams | K. & P.                     | 17                          |                             |                          |                                                  |                                            |
| None                      | K., P. & N                  | 234                         | 241                         | 475                      | 100                                              | 1696                                       |
| Cal. carbonate, 9.0 grams | K., P. & N                  | 360                         | 275                         | 565                      | 121                                              | 2053                                       |
| Coumarin, 9.0 grams       |                             | 4                           |                             |                          |                                                  |                                            |
| " 4.5 "                   |                             | 3                           |                             |                          |                                                  |                                            |
| " 9.0 "                   | K. & P.                     | 8                           |                             |                          |                                                  |                                            |
| " 4.5 "                   | K. & P.                     | 8                           |                             |                          |                                                  |                                            |
| " 9.0 "                   | K., P. & N                  | 101                         | 346                         | 447                      | 94                                               | 1596                                       |
| " 4.5 "                   | K., P. & N                  | 144                         | 245                         | 389                      | 82                                               | 1389                                       |
| Vanillin, 9.0 "           |                             | 4                           |                             |                          |                                                  |                                            |
| " 4.5 "                   |                             | 7                           |                             |                          |                                                  |                                            |
| " 9.0 "                   | K. & P.                     | 5                           |                             |                          |                                                  |                                            |
| " 4.5 "                   | K. & P.                     | 8                           |                             |                          |                                                  |                                            |
| " 9.0 "                   | K., P. & N                  | 142                         | 247                         | 289                      | 82                                               | 1389                                       |
| " 4.5 "                   | K., P. & N                  | 159                         | 220                         | 379                      | 80                                               | 1353                                       |
| Pyrogallol, 9.0 grams     |                             | 11                          |                             |                          |                                                  |                                            |
| " 4.5 "                   |                             | 11                          |                             |                          |                                                  |                                            |
| " 9.0 "                   | K. & P.                     | 16                          |                             |                          |                                                  |                                            |
| " 4.5 "                   | K. & P.                     | 17                          |                             |                          |                                                  |                                            |
| " 9.0 "                   | K., P. & N                  | 232                         | 252                         | 484                      | 102                                              | 1714                                       |
| " 4.5 "                   | K., P. & N                  | 221                         | 175                         | 396                      | 80                                               | 1396                                       |
| Carbon black, 9.0 grams   |                             | 11                          |                             |                          |                                                  |                                            |
| " 9.0 "                   | K. & P.                     | 23                          |                             |                          |                                                  |                                            |
| " 9.0 "                   | K., P. & N                  | 215                         | 168                         | 373                      | 78                                               | 1332                                       |

"K" means 4.5 grams of kainit; "N" means 4.5 grams of nitrate of soda; "P" means 4.5 grams of acid phosphate.

In Table VI are reported the yields obtained when coumarin, vanillin, pyrogallol and carbon black were used alone and in connection with fertilizer combinations. The green weight of the oat crop is shown in the third column of the table. A study of the results shows that both coumarin and vanillin have materially reduced the oat crop, whether used alone, or with kainit and phosphate, or with a complete fertilizer. Both of these compounds are very toxic to plants in water cultures, even when used in comparatively small amounts. In the work here reported, large proportions are used, based on the dry soil, and not on the

water that the soil could hold. Nine grams per pot of twenty pounds of soil is approximately equivalent to 1000 parts per million of soil. Therefore, the concentration of the solutions in which the oat crop started growth was very much greater than 1000 parts per million, if the compound was soluble in water, and if the soil did not remove the material from solution by absorption. It appears remarkable, then, that the oat crop, which was planted on the same day that the treatments were applied, did not show even greater injury from the vanillin and coumarin. On the other hand, neither pyrogallol nor carbon black appears to have influenced the yields of oats to a noticeable degree. In view of the fact that both of these substances have been shown to exert a great beneficial influence on plants grown in poor soil extracts, it might be expected that a similar influence might be shown when they are added to the poor soil itself, rather than to the poor soil extracts.

After the oat harvest, corn was planted in those pots which had received a complete fertilizer in the oat treatments. In each of these pots, the fertilizer treatment was repeated for the corn, but no further addition of the special treatments was given. The other pots which had been in the oat test were planted to cowpeas, and the results of this test will be given separately. In the fourth column of the table will be found the corn yields. These results are very interesting. The pots which had received 9 grams of vanillin or coumarin in connection with a complete fertilizer, produced much lighter yields of oats than did the pot which received a complete fertilizer alone; but the crop of corn following after the oats appears not to have been injured by the vanillin at all; the effect of the coumarin appears to have been slightly beneficial. Pyrogallol was without effect and carbon black slightly reduced the yield of corn. The results here presented show that this poor soil cannot be much improved in fertility by the use of such materials as pyrogallol or carbon black, neither of which carries plant food. If this soil is poor because of the presence of toxic bodies, then these bodies are of such nature that the above compounds fail to affect them, i. e., neither adsorbing nor reducing agents alters the productive capacity of the soil. The results show, also, that the fertility of

this soil is not much reduced by the addition of large quantities of compounds known to be toxic to plants in solution cultures, except when a crop is grown immediately after the addition of such compounds. This would indicate that these particular compounds undergo some change in the soil which renders them inert or actually beneficial.

As has already been noted, the early experiments conducted at this Experiment Station showed that pyridine and quinoline when applied to the soil, were beneficial to both oats and corn. The experiments conducted in 1914-1915 included pyridine, quinoline, nucleic acid, asparagine and naphthylamine, all of which are nitrogenous compounds. These were used in two ratios, the heavier ratio being 1000 parts per million of dry soil, and the lighter being 500 parts per million. The compounds were used without, and in connection with potassium and phosphorus. The results obtained with oats and corn are given in Table VII. All of the pots which were not planted to oats were planted to cowpeas instead; the results obtained with the peas are given elsewhere.

A study of the data obtained with the oat crop shows that the earlier experiments with pyridine and quinoline are fully substantiated. Nine c. c. of pyridine alone increased the oat crop materially; and with potash and phosphorus, the effect of such application is considerably greater than the effect of a complete fertilizer, with nitrate of soda as the source of nitrogen. The yields obtained from the quinoline treated pots are similar to those from the pyridine treated pots, though not quite so great. The fact that larger yields are obtained from the larger amounts of these two compounds shows that, *when these nitrogenous toxins are used in the soil*, and not in water cultures, *they lose their toxic properties entirely, and become highly beneficial*. Nor can it be argued that the addition of phosphorus and potassium increases the yield by exerting an antitoxic effect on these substances, because a similar increase in yield is obtained by adding these mineral elements to nitrate of soda, asparagine, and nucleic acid; neither of these latter materials is toxic to plants.



*Table VII. Effect of fertilizers, nucleic acid, naphthylamine, asparagine, pyridine and quinoline on crop yields in Cullers Field soil. Crops grown in 2-gallon pots in the greenhouse, 1914-1915.*

| SPECIAL TREATMENT       | Fertilizer<br>elements<br>applied | Green weight of<br>oats, grams | Green weight of<br>corn, grams | Combined wgt.<br>of two crops | Relative yields<br>fertilized<br>yield 100% | Relative yields<br>unfertilized<br>yield 100% |
|-------------------------|-----------------------------------|--------------------------------|--------------------------------|-------------------------------|---------------------------------------------|-----------------------------------------------|
| Check—no treatment      |                                   | 12                             | 16                             | 28                            |                                             |                                               |
| None                    | K*                                | 26                             |                                |                               |                                             |                                               |
| None                    | K. & P.                           | 16                             |                                |                               |                                             |                                               |
| Cal. carbonate, 9 grams | K. & P.                           | 17                             |                                |                               |                                             |                                               |
| None                    | K., P. & N                        | 234                            | 241                            | 475                           | 100                                         | 1696                                          |
| Nucleic acid, 9 grams   |                                   | 202                            | 111                            | 313                           | 66                                          | 1117                                          |
| 9 "                     | K. & P.                           | 328                            | 72                             | 400                           | 84                                          | 1428                                          |
| Asparagine, 9 grams     |                                   | 117                            | 181                            | 298                           | 62                                          | 1064                                          |
| 9 "                     | K. & P.                           | 325                            | 137                            | 462                           | 97                                          | 1650                                          |
| Naphthylamine, 9 grams  |                                   | 24                             | 89                             | 113                           | 24                                          | 403                                           |
| 9 "                     | K. & P.                           | 38                             | 73                             | 111                           | 23                                          | 396                                           |
| Pyridine, 9 c. c.       |                                   | 96                             | 200                            | 296                           | 62                                          | 1057                                          |
| " 4.5 c. c.             |                                   | 87                             |                                |                               |                                             |                                               |
| " 9 c. c.               | K. & P.                           | 305                            | 77                             | 382                           | 80                                          | 1364                                          |
| " 4.5 c. c.             | K. & P.                           | 217                            |                                |                               |                                             |                                               |
| Quinoline, 9 c. c.      |                                   | 44                             | 331                            | 365                           | 77                                          | 1303*                                         |
| " 4.5 c. c.             |                                   | 67                             |                                |                               |                                             |                                               |
| " 9 c. c.               | K. & P.                           | 206                            | 100                            | 306                           | 64                                          | 1092                                          |
| " 4.5 c. c.             | K. & P.                           | 137                            |                                |                               |                                             |                                               |

\* "K" means 4.5 grams of kainit; "P" means 4.5 grams of acid phosphate; "N" means 4.5 grams of nitrate of soda.

Naphthylamine proved to be of slight benefit to the crop of oats, and moderately helpful to the crop of corn following. Apparently it is decomposed very slowly in the soil, and is helpful only when decomposition takes place.

Asparagine and nucleic acid increased the oat crop to a remarkable degree, when used in connection with potassium and phosphorus; without the minerals, the effectiveness of both is reduced, though the absence of these mineral elements is much more evident with the asparagine treatment than with the nucleic acid treatment. A possible explanation of this difference between the yields obtained from these substances may be found in the difference in the composition of the

compounds themselves. Asparagine contains no phosphorus, while the nucleic acid does; and the phosphoric acid of the nucleic acid is set free during the decomposition of the compound in the soil. Since this is true, the absence of phosphorus in the treatment given would be more noticeable in the asparagine treated pots than in the nucleic acid treated pots.

Corn was planted in a number of the pots after the oats were harvested. The pots were treated as follows for the corn: the check pot remained untreated; the pot which had received a complete fertilizer for the oats was given a complete fertilizer for the corn, the same quantities of phosphate, kainit and nitrate being used in each case; while all of the remaining pots received 4.5 grams each of kainit and acid phosphate. It is very interesting to note the effect of the addition of potassium and phosphorus to those pots which had previously received nitrogenous compounds alone to oats. Without the minerals, the oat plants could not make use of the nitrogenous materials, and hence, there was an accumulation of nitrogen in those pots in which the minerals were lacking. Now, when these pots were treated with potassium and phosphorus and planted to corn, the limiting factor was removed, and there resulted enormous growth of the corn plants. Without exception, the high yielding oat pots proved to be the low yielding corn pots, and vice versa. No evidence is obtained from this work to show that pyridine or quinoline is toxic to plants, when it is added to the soil in which the plants are grown. On the contrary, it is definitely shown that these two compounds are useful sources of nitrogen, when used in connection with mineral fertilizers.

The effect of dihydroxystearic acid on plant growth when it is added to soil is of special interest in view of the great amount of work that has been done with it in water cultures, and the conclusions that have been drawn from these water cultures. The presence of even minute quantities of dihydroxystearic acid in water cultures greatly reduced the growth of wheat seedlings; and since this toxic compound has been isolated from soils, the conclusions were drawn that the infertility of the soils from which this compound was isolated, was due to its presence. If this be true, then it should be possible to increase the infertility of a

poor soil by adding to that soil large amounts of dihydroxystearic acid. In order to test this, a number of pots were treated as shown in the table below, and two crops grown, as in the case of the other experiments reported. The natural soil on which this test was made is infertile, apparently, because of a great deficiency of nitrogen, since neither phosphorus, nor potassium, nor lime, nor combinations of these increased the yields materially, while a complete fertilizer resulted in a most vigorous growth of plants, showing that it was the deficiency of nitrogen that caused the poor growth. Now, when dihydroxystearic acid is used alone or in combination with fertilizers and lime, the effect of the supposedly toxic compound is almost nil, as may readily be seen by a comparison of the yields reported in Table VIII. At no time during the progress of the work was there an apparent injury from this material although it has been shown to be decidedly toxic to plants, in solution cultures. A crop of corn followed after the oats, and growths obtained showed no indication of injury by dihydroxystearic acid. The corn received no second dose of the special treatment, but the fertilizer treatment given to the oats was repeated for the corn. Not all of the oat pots are represented in the fourth column of the table, for the reason that a number of pots carried peas instead of corn as the second crop; the cowpea results are given in a separate table. Apparently, the corn was slightly benefited by the previous application of dihydroxystearic acid; however, the difference between the yields from the pot with complete fertilizer and the pot with dihydroxystearic acid in addition to the complete fertilizer is most likely due to slight soil inequalities, or to unavoidable errors, rather than to any benefit derived from the special material added. Certainly, there is no indication that dihydroxystearic acid is injurious to corn or oats, under the conditions of this experiment. The tabulated results follow:

*Table VIII. Effect of fertilizers, lime, and dihydroxystearic acid on crop yields in Cullers Field soil. Crops grown in 2-gallon pots in the greenhouse, 1914-1915.*

| SPECIAL TREATMENT              | Fertilizer elements applied | Green weight of oats, grams | Green weight of corn, grams | Combined wgt. of two crops | Yield Check 100% |
|--------------------------------|-----------------------------|-----------------------------|-----------------------------|----------------------------|------------------|
| Check—no treatment             |                             | 12                          | 16                          | 28                         | 100%             |
| None                           | K.*                         | 26                          |                             |                            |                  |
| None                           | K. & P.*                    | 16                          |                             |                            |                  |
| Cal. carbonate, 9 grams        | K. & P.                     | 17                          |                             |                            |                  |
| None                           | K., P. & N                  | 234                         | 221                         | 475                        | 1696             |
| Cal. carbonate, 9 grams        | K., P. & N                  | 300                         | 275                         | 575                        | 2052             |
| Dihydroxystearic acid, 9 grams |                             | 12                          | 16                          | 28                         | 100              |
| " " 9 "                        | K.                          | 13                          | 16                          | 29                         | 103              |
| " " 9 "                        | K. & P.                     | 13                          |                             |                            |                  |
| " " 9 "                        | K., P. & N                  | 238                         | 302                         | 540                        | 1928             |
| Cal. carbonate, 9 grams        | K., P. & N                  | 242                         |                             |                            |                  |

\* "K" means 4.5 grams of kainit; "P" means 4.5 grams of acid phosphate; "N" means 4.5 grams of nitrate of soda.

Probably the most interesting of all of our experiments is reported in Table IX. The three pots used contained the same soil that was used in the experiments of 1913-1914. The check pot had been a check pot in an experiment conducted the previous year; the second pot on the table received nine grams each of acid phosphate and kainit the previous year; and the third pot had received 18 grams of pyridine. Based on the 10 pounds of air dry soil per pot, the eighteen gram doses are equivalent to 1000 parts per million, and the nine gram doses, to 500 parts per million of dry soil. Since none of the toxins applied singly had killed either oats or corn, and pyridine and quinoline had been helpful, when applied singly, it was thought possible that a combination of all the toxic compounds at hand might prevent growth entirely. Further, these few pots were used in this way in the hope of getting an insight into the action of such combinations, so as to have a basis for some future work.

In considering the data obtained, it should be remembered that the last pot in the table had had a heavy



application of pyridine in the experiments conducted previous to those here reported. During the two seasons in which these experiments were in progress, this third pot received a total of 81 grams of compounds which, in solution cultures, have been shown to be highly toxic to plants. And during the last season, this pot received 63 grams of toxic compounds, all of which were applied to the soil on the same day on which the oats were planted. If the soil used in this work weighed four million pounds to the acre, this 63 grams of toxins is equivalent to about seven thousand pounds per acre, based on the surface six inches. The phosphate and potash treatment which has been given the oats was repeated for the corn, but none of the special treatments were repeated.

By the time that the crop was two weeks old, the plants in the third pot began to take on a darker green color than those in the other two pots, and soon thereafter a vigorous stooling began. When the experiment was terminated, the plants of the third pot had stooled to such an extent that nearly the whole surface of the pot was covered with plant stems. A study of the photographs shown in Plate VIII will give a good idea of the appearance of the three pots just before harvest.

A crop of corn followed after the oats. As was the case with oats, the corn plants in the third pot made a better growth and had a darker green color than did those in the other two pots. These color and growth differences were noticeable by the time that the corn was a week old, and remained until the harvest of the crop. At no time was there the slightest indication of injury to either of the two crops by the enormously heavy applications of toxic compounds which had been made. Both the photographs and the crop weights give abundance of proof that the results obtained with soil cultures are radically different from those obtained with solution cultures. The weights of the green crops are presented in Table IX.

*Table IX. Effect of a combination of toxic compounds on crop yields on College Farm soil. Crops grown in 4-gallon pots in the greenhouse. 1914-1915.*

| SPECIAL TREATMENT                                                                                                                          | Fertilizer elements applied | Green weight of oats, grams | Green weight of corn, grams | Combined weight of two crops | Check 100% |
|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------|------------|
| Check—no treatment.....                                                                                                                    |                             | 48                          | 45                          | 93                           | 100        |
| Cal. carbonate, 36 grams.....                                                                                                              | K. & P.                     | 66                          | 52                          | 118                          | 126        |
| Cal. carbonate, 36 grams; pyridine, 18 c.c.; quinoline, 18 c.c.; vanillin, 9 grams; coumarin, 9 grams; dihydroxystearic acid, 9 grams..... | K. & P.                     | 446                         | 564                         | 1010                         | 1086       |

\* "K" means 4.5 grams of kainit; "P" means 4.5 grams of acid phosphate.

It is generally known that most of the poor sandy soils of the Southern states will produce very vigorous crops of cowpeas, even though they be so poor that they do not produce profitable crops of corn or cotton. Now, if the poor yields of corn or cotton obtained from such soils are due to the presence of toxic bodies in the soil, rather than to deficiencies of plant food, it would seem that cowpeas are not injured by the same compounds which do reduce the yields of the non-leguminous crops. It was decided to try to determine the effect on cowpea yields of certain of the compounds which had been used in the experiments already given. In the last column of Table X is shown the yields of cowpeas obtained when this crop was grown five months after the various toxic compounds had been added to the soil. Oats were grown immediately after the application of the special treatments had been given, and the oat yields are reproduced here for ease of comparison. The oats were harvested in the early spring before the plants were headed out; the pots were fertilized as shown in the fourth column, and peas planted. The weights given are for the stems and vines, excluding leaves and leaf stems. It was impossible to prevent leaf shedding in the greenhouse after the beginning of the hot weather of May and early June; and since some of the plants lost leaves more freely than did others, all leaves and leaf stems were

discarded so as to get comparable weights. The plants growing in the coumarin treated pots began shedding first and lost leaves most freely of all the pots in the experiment. On the other hand, the plants following the pyridine and quinoline treatments made the best early growth of all the pots in the test, these showing a rich dark green color from the beginning. However, there were only slight differences in the appearances of the crops on the various pots at the time that the experiment was terminated, with the exception of the coumarin treated plants. Coumarin was apparently injurious to the peas, causing the plants to take on a mottled yellow and green color, and greatly increasing the tendency to shed leaves.

*Table X. Effect of fertilizers, lime, carbon black, coumarin, vanillin, pyrogallol, pyridine, quinoline, and dihydroxystearic acid on crop yields in Cullers Field soil. Crops grown in 2-gallon pots in the greenhouse, 1914-1915.*

| SPECIAL TREATMENT                | Fertilizer elements applied to oats | Green weight of oats, grams | Fertilizer elements applied to peas | Air-dry weight of cowpeas, grams |
|----------------------------------|-------------------------------------|-----------------------------|-------------------------------------|----------------------------------|
| None                             | K*                                  | 26                          | K.                                  | 6.2                              |
| "                                | K. & P.*                            | 16                          | K. & P.                             | 6.1                              |
| Cal. carbonate, 9.0 grams        | K. & P.                             | 17                          | K. & P.                             | 7.6                              |
| Coumarin, 9.0 grams              |                                     | 4                           |                                     | 4.3                              |
| " 4.5 "                          |                                     | 3                           |                                     | 4.2                              |
| " 9.0 "                          | K. & P.                             | 8                           | K. & P.                             | 5.3                              |
| " 4.5 "                          | K. & P.                             | 8                           | K. & P.                             | 5.2                              |
| Vanillin, 9.0 grams              |                                     | 4                           |                                     | 5.5                              |
| " 4.5 "                          |                                     | 7                           |                                     | 7.3                              |
| " 9.0 "                          | K. & P.                             | 5                           | K. & P.                             | 7.1                              |
| " 4.5 "                          | K. & P.                             | 8                           | K. & P.                             | 7.4                              |
| Pyrogallol, 9.0 grams            |                                     | 11                          |                                     | 5.1                              |
| " 4.5 "                          |                                     | 11                          |                                     | 5.4                              |
| " 9.0 "                          | K. & P.                             | 16                          | K. & P.                             | 4.5                              |
| " 4.5 "                          | K. & P.                             | 17                          | K. & P.                             | 8.2                              |
| Carbon black, 9.0 grams          |                                     | 11                          |                                     | 6.1                              |
| " 9.0 "                          | K. & P.                             | 23                          | K. & P.                             | 6.0                              |
| Pyridine, 4.5 c. c.              |                                     | 87                          |                                     | 5.0                              |
| " 4.5 c. c.                      | K. & P.                             | 227                         | K. & P.                             | 6.3                              |
| Quinoline, 4.5 c. c.             |                                     | 67                          | K. & P.                             | 7.7                              |
| " 4.5 c. c.                      | K. & P.                             | 137                         | K. & P.                             | 5.4                              |
| Dihydroxystearic acid, 9.0 grams | K. & P.                             | 13                          | K. & P.                             | 5.6                              |

\* "K" means 4.5 grams of kainit; "P" means 4.5 grams of acid phosphate.

The yields of cowpeas obtained are so variable that conclusions of any kind would be out of place, and unwarranted. However, the writer believes that of the compounds tested, coumarin was the only one that had a detrimental effect on the crop of peas, basing this judgment upon the general appearance of the crops produced by the several pots in the experiment. The rather erratic results obtained are believed to be due to the very high temperatures which existed in the greenhouse during the hot weather of May and early June.

#### GENERAL DISCUSSION.

The data presented on the preceding pages of this publication are the results of experiments continuing over a period of two years. From the beginning of this work, the aim has been to parallel with soil cultures, the solution culture experiments reported by the Bureau of Soils, as far as means and time would permit. A large proportion of the soils of Alabama are naturally poor, and require fertilization for high yields. In the light of the experiments of the Bureau, this infertility might be due to the presence in the soil of compounds which are toxic to plants; and the liberal use of fertilizers is necessary in order to overcome or to antidote these toxic substances. If this be true, then the fertility of a soil should be increased in proportion to the removal of the inhibiting materials, since all normal soils are supposed to contain at all times a sufficient supply of available plant nutrients.

It has been shown to be possible to remove the toxic properties of a poor soil extract by the use of absorbents like ferric hydrate, finely divided quartz, or carbon black. Pyrogallol has also been shown to be very effective in certain cases in reducing the toxicity of such extracts. Logically, then, increased yields should be expected from poor soils which have been treated with carbon black, or pyrogallol, since the addition of these would remove the only cause of infertility, i. e., toxic compounds. In no case has this been found to be true, under the conditions of the tests herein reported. The addition of calcium carbonate proved to be of little benefit, showing that acidity was not the cause of the low yielding power of the soils used in this work.

On the other hand, the addition to soils of such toxic compounds as vanillin, coumarin, dihydroxystearic



acid, pyridine or quinoline failed to greatly increase the infertility of the infertile soils used. To be sure, the application of such compounds in ratios as great as 1000 parts per million of dry soil decreased the yields in some cases, where the crop was planted on the same day that these heavy applications were made. But when these compounds had been in the soil for a few months, the evidence shows that little or no toxic effects were to be found. Indeed, the nitrogenous compounds had a beneficial effect in all cases reported, though there was evidence that these may be harmful for a short time after the applications are made. This constitutes good evidence that rapid chemical or biochemical transformation of these compounds into beneficial or inert forms occurs in unsterilized soils under the conditions of these experiments. Slight injury to oats was apparent in most of the heavy treatments of pyridine and quinoline during the first weeks of growth; but this injurious action disappeared, and the pots so treated usually produced crops which compared favorably with those produced by the nitrate treated pots.

It is interesting to note that, had these experiments been terminated when the plants were only 15 days old, a quite different set of conclusions would have been drawn from the work. Both pyridine and quinoline would have been found to be harmful, while it is likely that vanillin and coumarin would have been recorded not injurious. Neither of these latter showed injury to oats during the first few days of growth; only in the later stages could their effect be noted, and that effect was a simple retardation of growth. It is very evident, then, that plants must be grown for considerable periods of time, if erroneous conclusions are to be avoided.

The increased amount of stooling induced in oats by pyridine and to a less extent by quinoline, is worthy of attention. The pyridine treated pots could be picked very easily after the plants were about 40 days old, due to vigorous stooling produced. Reference to the photographs on Plate II quite clearly shows the great number of stems produced on the pyridine treated pots. This increased stooling caused by pyridine has been noted both years, and in all of the soils tested.

Since the beginning of the work here reported, several papers have been published giving the results of tests with toxins in soil cultures.

Fraps (1) concludes from tests on a number of Texas soils, that pyrogallol has no beneficial effects on plants when used in connection with soil cultures. He also studied the effect of vanillin, coumarin, and dihydroxystearic acid when added to soils, and found little or no injury to result therefrom. It was found that vanillin and coumarin rapidly disappeared from the soils to which they had been applied.

Schreiner and Skinner (2) studied the toxic properties of salicylic aldehyde in soil, and found that even small quantities were harmful to plants. Six months after the application of salicylic aldehyde to field soils, enough of the compound still persisted to cause injury to growing plants.

Skinner (3) has reported pot experiments in which vanillin was added to three different soils on which wheat was grown. His results show that on soils of low fertility, vanillin was injurious; while on the fertile Hagerstown soil, no harmful effect resulted. In a field test at Arlington Farm, considerable injury to plants was caused by comparatively small amounts of vanillin; and the harmful effects of this compound persisted for six months, as shown by plant tests, and chemical examination of the soil for vanillin.

Upton and Powell (4) used vanillin in connection with soil cultures, and found little or no harmful effects on wheat, even with concentrations up to 1000 p. p. m. of soil. The toxic effect of salicylic aldehyde was found to be variable on different soils, but in all cases, the injury was considerably less than in solution cultures.

By means of soil cultures in pots, Davidson (5) studied the toxicity of coumarin and vanillin, finding that the germination of wheat was unimpaired, and the growth retarded but little. He concludes that "On the whole, it might be said that these experiments would hardly lend much support to the assumption that the presence in the soil of organic substances toxic in water cultures is a factor of considerable importance under field conditions, when the other factors of plant growth are normally good."

(1) Texas Station Bulletin 174.

(2) Bul. 108, U. S. Dept. Agri.

(3) Bul. 164, U. S. Dept. Agri.

(4) Jour. Ind. & Eng. Chem. 7:5.

(5) Jour. Am. Soc. Agronomy, 7:5

The experiments conducted by Fraps, by Upson and Powell, and by Davidson gave results which are in almost complete agreement with our work; while the tests by Schreiner and Skinner do not accord closely.

Where soil culture experiments fail to give concordant results, in all probability, such lack of agreement is due to the differences between the soil types used in the experiments.

It would seem clear that the soil toxin theory cannot apply to the soils used in these experiments. In each case, infertility of the check pots can be completely explained as being due to a lack of mineral nutrients. It is also evident from the data here presented that solution culture and soil culture experiments fail to agree. Consequently, the utmost caution should be observed in drawing conclusions in regard to the causes of soil fertility or infertility, from solution culture studies alone.

#### GENERAL SUMMARY OF ALL EXPERIMENTS.

1. The first year's work is substantiated by the data obtained the second year.

2. Soils very deficient in nitrogen cannot be much benefited by the addition of lime, phosphorus and potassium. Nitrogen alone is much more effective than a combination of these three elements.

3. The addition of large amounts of coumarin and vanillin depresses the yield of oats, when the oats are planted immediately after the application of these compounds.

4. Fertilizers do not prevent the bad effects of coumarin and vanillin.

5. Lime, carbon black, and pyrogallol are of little or no benefit to plants, when they are added to soils used in these experiments.

6. Neither pyrogallol nor carbon black increased the effectiveness of fertilizers.

7. Pyridine and quinoline, both of which are nitrogenous compounds, have been found to be highly beneficial to both oats and corn in all soils tested.

8. The addition of potassium and phosphorus greatly increases the beneficial effects of pyridine and quinoline.

9. The action of potassium and phosphorus in increasing the effectiveness of pyridine and quinoline cannot be regarded as an antitoxic action. These two mineral elements greatly increased the effect of asparagine, nucleic acid, and nitrate of soda, none of which is toxic to plants.

10. Dihydroxystearic acid had absolutely no bad effect on either oats or corn. Larger yields of both crops were obtained in the presence of dihydroxystearic acid and a complete fertilizer, than with a complete fertilizer alone.

11. Naphthylamine, a nitrogenous compound, is slightly beneficial to oats and corn, but apparently it is changed very slowly in soils; and unless it is decomposed, it has no effect one way or another.

12. Asparagine and nucleic acid, neither of which is toxic to plants in solution cultures, proved to be very beneficial when used in soil cultures.

13. A normal soil can apparently dispose of enormous quantities of organic compounds through physical, chemical, and biochemical action.

14. The results obtained with soil cultures fail to agree with those obtained with solution cultures, when the aim is to show the toxicity or non-toxicity of chemical compounds.

15. Soil fertility problems cannot be solved by means of short time solution culture studies. Soil fertility studies with the soil left out, cannot be depended upon to answer correctly the complex questions involved in soil fertility work.



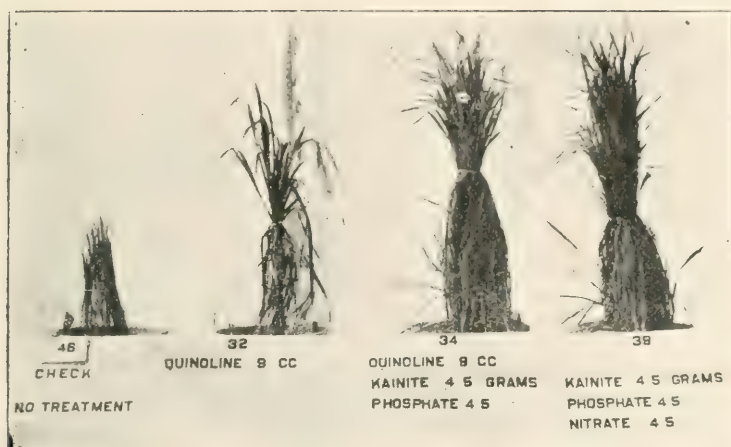


Fig. 1. Immediate effect of quinoline on oats when applied alone and in connection with fertilizers.



Fig. 2. Residual effect on corn of quinoline when applied to the previous crop of oats.



Fig. 1. Immediate effect on oats of pyridine applied alone and in connection with fertilizer.



Fig. 2. Residual effect on corn of pyridine applied to the previous crop of oats.

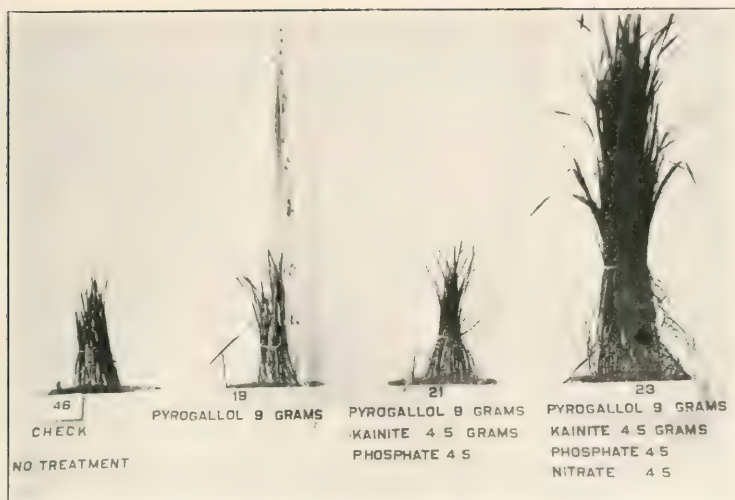


Fig. 1. Immediate effect on oats of pyrogallol applied alone and in connection with fertilizers.



Fig. 2. Residual effect on corn of pyrogallol and carbon black applied to the previous crop of oats.

(Plate III, fig. 2, pot No. 24, blurred line at bottom of the legend should read, "To corn, K. P. and N.")

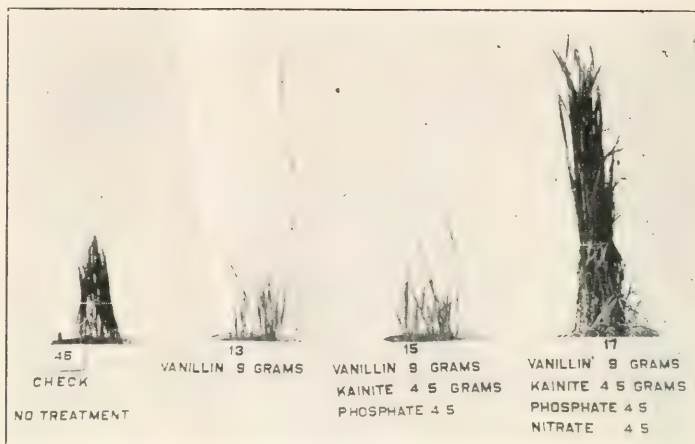


Fig. 1. Immediate effect on oats of vanillin applied alone and in connection with fertilizers.



Fig. 2. Residual effect on corn of vanillin to the previous crop of oats.



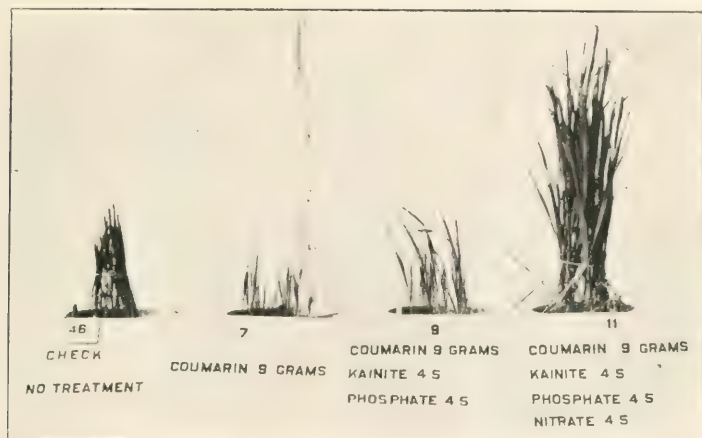


Fig. 1. Immediate effect of coumarin on oats when applied alone and in connection with fertilizers.



Fig. 2. Residual effect on corn of coumarin applied to the previous crop of oats.

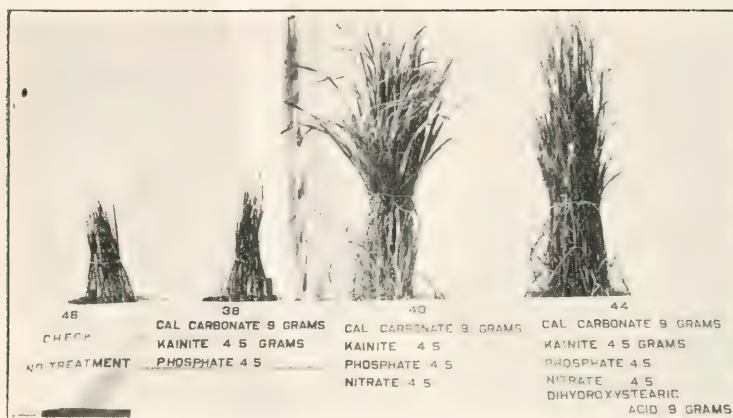


Fig. 1. Immediate effect of dihydroxystearic acid on oats when used in connection with a complete fertilizer.



Fig. 2. Residual effect on corn of dihydroxystearic acid applied to previous crop of oats.



Fig. 1. Immediate effect of dihydroxystearic acid on oats when used alone and in connection with kainit.



Fig. 2. Residual effect on corn of dihydroxystearic acid applied to previous crop of oats.

# PLATE VIII.



Fig. 1. Immediate effect on oats of a combination of organic compounds in connection with fertilizer and lime.

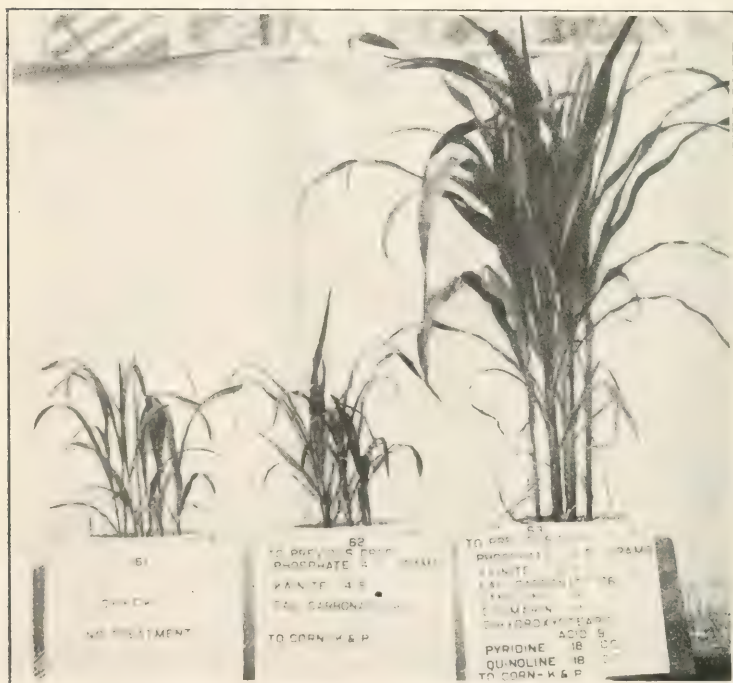


Fig. 2. Residual effects on corn of a combination of organic compounds applied to the previous crop of oats.



**ALABAMA**

**Agricultural Experiment Station**

OF THE

**Alabama Polytechnic Institute**

**AUBURN**

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**Cottonseed Meal Compared With Velvet  
Beans For Fattening Steers**

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By  
G. S. TEMPLETON, Animal Husbandman  
E. GIBBENS, Assistant

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1916  
Post Publishing Company  
Opelika, Ala.

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In co-operation with United States Department of Agriculture.

# COTTONSEED MEAL COMPARED WITH VELVET BEANS FOR FATTENING STEERS

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BY

G. S. TEMPLETON

AND

E. GIBBENS

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## INTRODUCTION.

The velvet bean is a comparatively new feed. The crop is usually fed by turning cattle and hogs into the field after the vines have been killed by frost. This method of harvesting is satisfactory on soils of a sandy character, but on the heavier types of soils a good many beans are wasted during bad weather and the fields are damaged by the stock tramping them.

The bean makes a very heavy vine growth and is grown extensively by some farmers to add humus to the soil. In this practice, after the frost kills the vines, the mature beans are gathered by hand and the vines are plowed under.

The experiment reported in this bulletin was made to determine the value of the velvet bean as a concentrate for fattening steers. This work is only a preliminary report of the experiments in feeding velvet beans. The test is to be repeated during the winter of 1916-1917.

## OBJECT OF THE EXPERIMENT.

This experiment was planned with a view to comparing the relative feeding value of cottonseed meal and velvet beans in pods as the concentrate part of a ration for fattening steers.

## THE CATTLE.

The pictures of Lot 6 and Lot 7, taken at the time the experiment was started and when completed, give a good idea of the type of steers used. Part of the steers were raised on the farm at Allenville and the remainder were purchased in Marengo and neighboring counties. None of the steers were pure bred, but

all were either Hereford, Shorthorn or Angus grades. The steers varied from one to two years of age. The average weight of each animal at the beginning of the experiment was 584 pounds.

#### GENERAL PLAN OF THE WORK.

The steers were fed under average farm conditions. The feeding test was conducted on the farm of Judge B. M. Allen, at Allenville, Alabama. Judge Allen furnished the cattle and the feeds, and the experiment was planned and carried on under the supervision of the authors of this bulletin. Mr. E. Gibbens had personal charge of the cattle throughout the experiment.

The feed lots were located in a cedar grove. The cedar trees gave all the protection the steers had during the experiment. The lots had a southern exposure and were well drained. The manure was hauled out of the lots every few days. No bedding was used, but the lots were dry enough so the steers could lie down comfortably. Pure water from a deep well was kept before the steers at all times. Rock salt was kept in the feed troughs continually.

The steers were fed twice each day. The concentrates and roughage were mixed thoroughly by hand in the feed troughs. The amount of feed was regulated so that it was consumed in a few hours. At the close of the experiment the steers were shipped, with sixty head used in other experiments, to the market in St. Louis, Missouri.

#### PRICE AND CHARACTER OF FEEDS USED.

The prices used in this bulletin are the prices actually paid for the steers. The corn silage was made on the farm. The silage corn would have yielded twenty-five bushels of corn per acre. All of the feeds were of good quality. The corn silage was bright. The cottonseed meal was fresh, bright and of a high grade. The velvet beans were well matured and of a good quality.

The prices of feeds are as follows:

|                     |                 |
|---------------------|-----------------|
| Cottonseed meal     | \$35.00 per ton |
| Velvet beans in pod | 18.00 per ton   |
| Corn silage         | 2.50 per ton    |

#### METHOD OF FEEDING AND HANDLING THE STEERS.

As stated before, some of the steers were raised on the farm at Allenville and the remainder were bought in Marengo and neighboring counties in the spring and



early summer. The low cost of the steers at the time they went into the feed lot, 4.95 cents per pound, was due to the fact that they were purchased in thin condition in the spring and grazed during the summer. The cheap gains made during the summer considerably reduced the cost per pound of the steers at the beginning of the feeding period.

It is usually considered safe to feed steers when a two-cent margin is possible on them. That is, the selling price of the steer should be at least two cents per pound higher than the cost price. Usually the gains that are made in the feed lot, with feeds at the present prices, will cost as much as the pounds gained will sell for. The profit to the feeder comes largely from the increased value on the original weight of the steer, due to the gains the steer puts on in the feeding operation.

The steers had the run of the stalk fields after the permanent pastures began to fail. They were in the stalk fields during the entire month of November. They were all dehorned the first of November and were entirely healed by the time the experiment started.

The forty steers used in this experiment, and sixty others, were given a preliminary feed of sixteen days while they had the run of the stalk fields. The preliminary feeding was done to accustom them to feeding and handling and to secure a uniform fill. Each steer received two and one-half pounds of shelled corn, one-half pound of cottonseed meal and twelve pounds of silage daily for the sixteen day period. On the 18th day of December, 1915, the steers were weighed, and divided into lots for the test, and each steer tagged with a metal ear tag so that individual records could be kept. The steers were weighed on three consecutive days at the beginning of the experiment and the average of the three weights was used as the initial weight. Fourteen days later they were weighed by lots, and on the twenty-eighth day individual weights were taken, this procedure being repeated until the end of the test. The experiment continued for ninety-seven days. Hence the steers were fed for one hundred and thirteen days, including the preliminary period.

#### DAILY RATIONS.

The amount of roughage was regulated by the appe-

tite of the steer. The concentrates were increased from time to time as the steer would take the increase without showing signs of going off feed.

The feeder should watch fattening steers very closely for signs of going off feed. Considerable time and loss of gain is usually experienced in getting a steer back on feed again. The symptoms that usually indicate that a steer is not doing well are the loss of the healthy appearance of the coat of hair and the droppings becoming thin and sour. If these symptoms develop, the amount of feed should be reduced. Steers will feed more uniformly if individuals of the same age and size are grouped together in the feed lot.

The following table outlines, by twenty-eight day periods, the amount of feed given each steer daily:

TABLE I. *Showing average amount of feed consumed daily, per steer, December 18, 1915, to March 24, 1916, (97 days.)*

| Period             | Lot 6                          |       | Lot 7                                 |       |
|--------------------|--------------------------------|-------|---------------------------------------|-------|
|                    | Cottonseed Meal<br>Corn Silage |       | Velvet Beans (in pods)<br>Corn Silage |       |
|                    | Pounds                         |       | Pounds                                |       |
| First 28 days ---- | Cottonseed meal                | 2.76  | Velvet beans --                       | 5.70  |
|                    | Corn silage ----               | 35.4  | Corn silage ----                      | 31.07 |
| Second 28 days --- | Cottonseed meal                | 4.00  | Velvet beans --                       | 9.44  |
|                    | Corn silage ----               | 40.43 | Corn silage ----                      | 26.80 |
| Third 28 days ---  | Cottonseed meal                | 4.75  | Velvet beans --                       | 12.21 |
|                    | Corn silage ----               | 39.42 | Corn silage ----                      | 20.21 |
| Last 13 days ----- | Cottonseed meal                | 6.46  | Velvet beans --                       | 12.00 |
|                    | Corn silage ----               | 43.03 | Corn silage ----                      | 25.60 |

During the first two weeks of the test the velvet beans and pods were ground coarse so they could be mixed thoroughly with the silage. At the end of the two-weeks period it was evident that the steers relished the ration and at this time the grinding of the beans was discontinued. During the remainder of the experiment the beans in the pods were fed whole. They were thoroughly mixed with the silage so that each steer would get only his share.

The steers in Lot 6 ate on an average 2.76 pounds of cottonseed meal and 35.40 pounds of silage daily during the first twenty-eight days. The amount of meal was gradually increased until at the close of the experiment each steer was eating 6.46 pounds of cottonseed meal per day.

The steers in Lot 7 ate on an average 5.70 pounds of velvet beans and 31.07 pounds of silage during the first twenty-eight days. The amount of beans was gradually increased until in the third period the steers consumed 12.21 pounds per day. This amount was decreased for the last thirteen days as the steers did not readily clean up this amount of beans. The steers in Lot 7 did not consume as much silage as Lot 6.

Both rations were relished by the steers and at no time during the test was there any trouble due to steers going off feed.

TABLE II. *Average weights and gains, December 18, 1915 to March 24, 1916, (97 days.)*

| <i>Number of Steers</i> | <i>Ration</i>        | <i>Average Initial Weight of Each Steer</i> | <i>Average Final Weight of Each Steer</i> | <i>Average Total Gain of Each Steer</i> | <i>Average Daily Gain of Each Steer</i> |
|-------------------------|----------------------|---------------------------------------------|-------------------------------------------|-----------------------------------------|-----------------------------------------|
| 20                      | Cottonseed meal ---- | Pounds                                      |                                           |                                         | Pounds                                  |
|                         | Corn silage -----    | 589                                         | 746.25                                    | 157.25                                  | 1.60                                    |
| 20                      | Velvet beans in pods |                                             |                                           |                                         |                                         |
|                         | Corn silage -----    | 580.25                                      | 727.45.                                   | 147.20                                  | 1.50                                    |

All of the steers in both lots, except one in Lot 6, made satisfactory but not unusual gains. The lack of gain in this individual steer was due to his being a very poor feeder and could in no way be attributed to the ration, as the other nineteen head made good gains. The average gain daily, per head, for the 97 days was 1.60 pounds and 1.50 pounds in Lot 6 and Lot 7 respectively.

This experiment was closed earlier than had been planned, due to a shortage of silage. On account of the short feeding period the steers did not have the finish to be marketed to the best advantage. Careful inspection of the steers of the two lots on foot failed to show any perceptible difference in their finish. Moreover, careful inspection of the warm carcasses by packing house experts showed no appreciable difference between carcasses of the two lots.

#### QUANTITY AND COST OF FEED REQUIRED TO MAKE ONE HUNDRED POUNDS OF GAIN.

In feeding operation the real value of a feed, or combinations of feeds, is measured by the number of pounds of feed required to make one hundred pounds of gain in live weight. Table III shows the quantity

of feed required to make one hundred pounds of gain and the cost of the gains under the conditions of this experiment:

TABLE III. *Quantity and cost of feed required to make one hundred pounds of gain, December 18, 1915, to March 24, 1916, (97 days.)*

| <i>Lot</i> | <i>Ration</i>         | <i>Pounds of Feed to make 100 Pounds of Gain</i> | <i>Cost of Feed to Make 100 Pounds of Gain</i> |
|------------|-----------------------|--------------------------------------------------|------------------------------------------------|
| 6          | Cottonseed meal ----  | 258.18 meal                                      |                                                |
|            | Corn silage -----     | 2408.58 silage                                   | \$7.52                                         |
| 7          | Velvet beans in pod-- | 635.12 beans                                     |                                                |
|            | Corn silage -----     | 1654.75 silage                                   | \$7.77                                         |

A comparison of the costs of gains of Lot 6 and Lot 7 shows a very slight difference in favor of Lot 6. In this test one pound of cottonseed meal was equal to two and one-half pounds of velvet beans in pods. Lot 7, however, consumed only two-thirds as much silage as Lot 6. It is evident that the pods tended to reduce the consumption of silage. The cost of making one hundred pounds of gain was practically the same for the two rations. This indicates that in this experiment velvet beans in the pod at \$18.00 per ton were practically as profitable as high grade cottonseed meal at \$35.00 per ton. That is, according to this experiment, a feeder could afford to pay nearly half as much per ton for unhulled and unground velvet beans as for a ton of high grade cottonseed meal.

#### FINANCIAL STATEMENT.

The statement for the feeding test is based on the prices the steers actually cost and the local prices for feeds. Steers of the same age and quality, fed under similar conditions, should return the same profits on the same rations. Prices of steers and of feeds vary from year to year, so the feeder must make corrections in his estimates for feeding operations on the basis of local prices.

#### LOT 6. COTTONSEED MEAL AND CORN SILAGE:

|                                                     |          |
|-----------------------------------------------------|----------|
| To 20 steers, 11780 lbs. @ 4.95 cents per lb. ....  | \$583.11 |
| To 8120 lbs. cottonseed meal @ \$35.00 per ton .... | 142.10   |
| To 75750 lbs. corn silage @ \$2.50 per ton .....    | 94.68    |
| To freight, yardage and commission .....            | 98.00    |
|                                                     | <hr/>    |
|                                                     | \$917.80 |
| By sale, 6 steers, 5180 lbs. @ 7.90 per cwt. ....   | \$409.22 |



|                                                    |        |
|----------------------------------------------------|--------|
| By sale, 13 steers, 8750 lbs. @ 7.50 per cwt. .... | 656.25 |
| By sale, 1 steer, 540 lbs. @ 5.50 per cwt. ....    | 29.70  |

|                        |           |
|------------------------|-----------|
|                        | <hr/>     |
| Total profit .....     | \$1095.17 |
| Profit per steer ..... | \$177.28  |
|                        | <hr/>     |
|                        | 8.86      |

#### LOT 7. VELVET BEANS IN POD AND CORN SILAGE:

|                                                    |          |
|----------------------------------------------------|----------|
| To 20 steers, 11605 lbs. @ 4.95 per lb. ....       | \$574.44 |
| To 18700 lbs. velvet beans @ \$18.00 per ton ..... | 168.30   |
| To 48716 lbs. corn silage @ \$2.50 per ton .....   | 60.89    |
| To freight, yardage and commission .....           | 98.00    |

|                                                     |          |
|-----------------------------------------------------|----------|
|                                                     | <hr/>    |
|                                                     | \$901.63 |
| By sale, 4 steers, 3290 lbs. @ 7.90 per cwt. ....   | \$259.91 |
| By sale, 16 steers, 10670 lbs. @ 7.50 per cwt. .... | 800.25   |

|                        |           |
|------------------------|-----------|
|                        | <hr/>     |
| Total profit .....     | \$1060.16 |
| Profit per steer ..... | \$158.53  |
|                        | <hr/>     |
|                        | 7.92      |

#### SUMMARY STATEMENTS.

1. In this experiment one pound of cottonseed meal took the place of two and one-half pounds of velvet beans in pods. The velvet bean lot, however, required only two-thirds as much silage as the cottonseed meal lot.

2. The cost per 100 pounds of gain was practically equal, when cottonseed meal cost \$35.00 per ton and unhulled velvet beans \$18.00 per ton.

3. On the above basis, the profit per steer was, on the velvet bean ration, \$7.92, and on the cottonseed meal ration, \$8.86.

4. The velvet bean ration was relished by the steers.

5. In feeding velvet beans in pods with silage it was found that it was not necessary to grind the beans.

6. The gains made by the steers in each lot were satisfactory: Lot 6, (cottonseed meal) gained an average of 1.6 pounds per day; Lot 7, (velvet beans) gained an average of 1.5 pounds per day.



LOT 6. *Fed cottonseed meal and corn silage.*



Fig. 1. Photo taken at beginning of experiment.



Fig. 2 Photo taken at end of experiment.

PLATE II

LOT 7. *Fed velvet beans in pod and corn silage.*



Fig. 1. Photo taken at beginning of experiment.



Fig. 2. Photo taken at end of experiment.



Twenty-ninth Annual Report

OF THE

Agricultural Experiment  
Station

OF THE

Alabama Polytechnic Institute

Auburn, Alabama

January, 1917



Twenty-ninth Annual Report

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Auburn, Alabama

January, 1917





ALABAMA POLYTECHNIC INSTITUTE.

Auburn, Ala., Jan. 30, 1917.

Governor Charles Henderson,  
Executive Department,  
Montgomery, Ala.

Sir:

I have the honor herewith to transmit to you the Twenty-ninth Annual Report of the Agricultural Experiment Station of the Alabama Polytechnic Institute.

This report is made in accordance with the Act of Congress approved March 2, 1887, establishing agricultural experiment stations, and the Act of Congress approved March 16, 1906, known as the Adams Act.

Respectfully,  
CHAS. C. THACH,  
President.



Auburn, Ala., Jan. 29, 1917.

Dr. C. C. Thach, President,  
Alabama Polytechnic Institute,  
Auburn, Ala.

Sir:

I herewith submit the Twenty-ninth Annual Report of the Experiment Station of the Alabama Polytechnic Institute for the fiscal year ending June 30, 1916.

It contains the detailed report of the Director and Agriculturist, the Treasurer, the Chemists, the Veterinarian, the Botanist, the Horticulturist, the Entomologist, the Plant Pathologist, and the Animal Husbandman, for the year ending December 31, 1916.

Respectfully submitted,

J. F. DUGGAR,  
Director, Experiment Station.





## AGRICULTURAL EXPERIMENT STATION.

### TRUSTEES.

|                                                   |                      |
|---------------------------------------------------|----------------------|
| His Excellency, Charles Henderson, President..... | Ex-Officio           |
| W. F. Feagin, Superintendent of Education.....    | Ex-Officio           |
| A. W. Bell.....                                   | Anniston, Ala.       |
| Harry Herzfeld.....                               | Alexander City, Ala. |
| Oliver R. Hood.....                               | Gadsden, Ala.        |
| C. S. McDowell, Jr.....                           | Eufaula, Ala.        |
| W. K. Terry.....                                  | Birmingham, Ala.     |
| W. H. Oates.....                                  | Mobile, Ala.         |
| T. D. Samford.....                                | Opelika, Ala.        |
| R. F. Kolb.....                                   | Montgomery, Ala.     |
| J. A. Rogers.....                                 | Gainesville, Ala.    |
| C. M. Sherrod.....                                | Courtland, Ala.      |

### COMMITTEE OF TRUSTEES ON EXPERIMENT STATION.

|                         |             |
|-------------------------|-------------|
| R. F. KOLB.....         | Montgomery  |
| A. W. BELL.....         | Anniston    |
| J. A. ROGERS.....       | Gainesville |
| C. S. McDOWELL, JR..... | Eufaula     |

## STATION STAFF.

C. C. THACH, President of the College.

J. F. DUGGAR, Director.

### AGRICULTURE:

J. F. Duggar, Agriculturist.  
E. F. Cauthen, Associate.  
M. J. Funchess, Associate.  
J. T. Williamson, Field Agt.  
O. H. Sellers, Assistant.  
O. L. Howell, Assistant.  
F. E. Boyd, Assistant. \*

### VETERINARY SCIENCE:

C. A. Cary, Veterinarian.

### CHEMISTRY:

J. T. Anderson, Chemist.  
Soils and Crops.  
C. L. Hare, Physiological  
Chemist.  
———, Assistant.

### BOTANY:

W. J. Robbins, Botanist.  
A. B. Massey, Assistant.

### PLANT PATHOLOGY:

G. L. Peltier, Pathologist.

### HORTICULTURE:

G. C. Starcher, Horticulturist  
J. C. C. Price, Associate.  
P. O. Davis, Field Agent.

### ENTOMOLOGY:

W. E. Hinds, Entomologist.  
F. L. Thomas, Assistant.  
E. A. Vaughan, Field Asst.

### ANIMAL HUSBANDRY:

G. S. Templeton, Animal  
Husbandman.  
H. C. Ferguson, Assistant.  
E. Gibbens, Assistant.  
F. W. Wendt, Assistant.  
A. E. Hayes, Assistant.

### AGRICULTURAL ENGINEERING:

R. U. Blasingame, Agricul-  
tural Engineer.

\*In co-operation with United States Department of Agriculture.

# REPORT OF HATCH AND ADAMS FUNDS FOR 1915-1916.

## RECEIPTS.

|                                    | Hatch       | Adams       |
|------------------------------------|-------------|-------------|
| To amount from U. S. Treasury .. . | \$15,000.00 | \$15,000.00 |

## DISBURSEMENTS.

|                                          |             |             |
|------------------------------------------|-------------|-------------|
| By Salaries .. .                         | \$ 7,450.00 | \$10,096.80 |
| By Labor .....                           | 2,401.08    | 1,771.52    |
| By Publications .. .                     | 1,293.71    |             |
| By Postage and Stationery .. .           | 276.25      | 162.98      |
| By Freight and Express .....             | 510.28      | 259.04      |
| By Heat, Light, Water and Power .....    | 410.46      | 343.14      |
| By Chemicals and Laboratory Supplies ..  | 139.92      | 489.60      |
| By Seeds, Plants and Sundry Supplies ..  | 586.84      | 230.39      |
| By Fertilizers .....                     | 361.89      | 104.14      |
| By Feeding Stuffs .....                  | 494.83      | 372.20      |
| By Library .. .                          | 253.69      | 62.21       |
| By Tools, Machinery and Appliances .. .  | 215.06      | 55.09       |
| By Furniture and Fixtures .....          | 49.55       | 84.15       |
| By Scientific Apparatus and Specimens .. | 7.22        | 219.19      |
| By Live Stock .....                      | 268.00      | 183.80      |
| By Traveling Expenses .....              | 164.17      | 238.02      |
| By Contingent Expenses .....             | 20.00       |             |
| By Buildings and Land .....              | 97.05       | 327.70      |
| Total .....                              | \$15,000.00 | \$15,000.00 |

State of Alabama:

Lee County.

Personally appeared before me, B. L. Shi, a Notary Public in and for said county, M. A. Glenn, known to me as Treasurer of the Alabama Polytechnic Institute, who, being duly sworn, deposes and says the above foregoing account is true and correct. Witness my hand this 19th day of January, 1917.

B. L. SHI,

Notary Public, Lee County.

This is to certify that I have compared the account with the ledger account of the Treasurer, and this is a correct transcript of the same.

CHAS. C. THACH,

President Alabama Polytechnic Institute.





# REPORT OF DIRECTOR AND AGRICULTURIST.

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J. F. DUGGAR.

---

Dr. C. C. Thach, President,  
Alabama Polytechnic Institute,  
Auburn, Alabama.

Sir:

I respectfully submit the following report for the past year of the work under my charge as Director and Agriculturist of the Alabama Experiment Station:

## PUBLICATIONS.

During the calendar year 1916 the publications of the Alabama Experiment Station consisted of the annual report, six bulletins, one circular, seven press bulletins, and two indexes, making a total of sixteen publications. These constituted a total of 224,000 copies and an aggregate of 2,534,500 pages in all editions. The titles and authors are given below:

Bulletion No. 187: Cabbage; by the Associate Horticulturist and the Field Agent in Horticulture.

Bulletin No. 188: Boll Weevil in Alabama; by the Entomologist. (From the Local Experiment Fund).

Bulletin No. 189: Wilt Resistant Varieties of Cotton; by the Associate Agriculturist. (From the Local Experiment Fund).

Bulletin No. 190: Citrus Canker; by the Pathologist.

Bulletin No. 191: The Effect of Certain Organic Compounds on Plant Growth; by the Associate Agriculturist.

Bulletin No. 192: Cottonseed Meal Compared With Velvet Beans for Fattening Steers; by the Animal Husbandman and Assistant. (From the Local Experiment Fund).

Circular No. 34: Annual Report of the Director of the Experiment Station on Work Done Under the Local Experiment Law in 1915. (From the Local Experiment Fund).

Press Bulletin No. 83: Controlling the Boll Weevil by Collecting Weevils and Infested Squares; by the Entomologist. (From Local Experiment Fund).

Press Bulletin No. 84: Wilt Resistant Varieties of Cotton; by the Associate Agriculturist and Recorder. (From the Local Experiment Fund).

Press Bulletin No. 85: Separation of Corn Cockle Seed from Commercial Narrow Leaf Vetch Seed; by the Assistant in Agriculture.

Press Bulletin No. 86: Tests of Varieties of Corn in 1916; by the Associate Agriculturist.

Press Bulletin No. 87: Varieties of Fruits for a Home Orchard in Alabama; by the Associate Horticulturist and Field Agent in Horticulture. (From the Local Experiment Fund).

Press Bulletin No. 88: Tests of Varieties of Cotton in 1916; by the Associate Agriculturist.

Press Bulletin No. 89: The Home Orchard; Setting and Care; by the Associate Horticulturist and Field Agent in Horticulture. (From the Local Experiment Fund).

Bulletin Index for Volume 22. (1914).

Bulletin Index for Volume 23. (1915).

#### STAFF.

Several changes have occurred among the heads of departments during the past year. Dr. W. J. Robbins, of Cornell University, was appointed Botanist of the Station in succession to Dr. J. S. Caldwell, who had resigned to accept a position in another state. Dr. Robbins began work in February, 1916.

A vacancy, created by the resignation of Dr. F. A. Wolf, to accept a position in another state, was filled in June, 1916, by the appointment of Dr. Geo. L. Peltier, then of the University and Experiment Station of Illinois.

Several changes have occurred among the assistants in the several departments, as may be noted from the list of the Station Staff published on another page.

#### REPORT OF DEPARTMENTS.

The attached reports of the Botanist, the Acting Horticulturist, the Entomologist, the Plant Pathologist, the Animal Husbandman, the Chemists, and the Veterinarian, present a brief statement of the experimental work in their respective departments.

#### AGRICULTURAL DEPARTMENT.

(Work Under Hatch and Adams Funds from Congress).

Plant breeding has continued to be one of the lines of work

that has occupied much of the time of the members of this department. The large amount of data accumulated on correlations between yield and various qualities of the corn plant and corn ear have been to a large extent summarized and put in shape for publication. There remains to be added the field results for 1916, and a study of the correlations between certain additional qualities, for which the data are on record.

The breeding of oats has been continued, and field tests indicate the practical value of this. It is hoped that at an early date there may be prepared for publication a part of the data accumulated by a number of year's breeding of cotton and oats. Field tests, both at Auburn and other parts of the State, continue to give increasing evidence of the value of the strains of cotton, corn, and oats, evolved as a result of the breeding work at Auburn.

It is believed also that the results when fully analyzed will throw important light on some of the details of plant breeding that are important from a scientific standpoint.

The following is a list of the principal field experiments conducted on the Station farm in 1916:

- Alfalfa, fertilizer, variety and culture experiments.
- Barley, variety tests.
- Cotton, effects of planting light and heavy seed.
- Cotton, variety tests.
- Cotton, breeding with Cook, Cleveland and hybrids.
- Cotton, tests of long staple varieties.
- Cotton, culture experiments, including thick and thin planting.
- Cotton, sub-soiling.
- Cotton, time of applying nitrate of soda.
- Corn, variety tests.
- Corn, Williamson versus other methods of culture.
- Corn, best rotation for.
- Cowpeas, variety and culture tests.
- Cowpeas, for soil improvement.
- Clovers, tests of species and varieties.
- Clovers, best plants for sowing with legumes.
- Grains, as forage crops.
- Forage crops, tests of many species and varieties.

Grasses, tests of species and varieties.

Hog crops, chufas, peanuts, soybeans, etc.

Hemp.

Kudzu.

Nitrogen, best sources of.

Oats, variety tests, methods of seeding, and time of sowing.

Oats, breeding experiments.

Oats, fall sown versus spring strains.

Phosphates, raw versus acid, versus basic.

Peanuts, variety tests.

Rotation experiments.

Rye, variety tests.

Silage, yield of different crops for.

Soybean and cowpea mixtures for hay.

Soybeans, varieties.

Soybeans, tests of varieties.

Sorghum, tests of varieties.

Subsoiling.

Sudan grass, culture tests.

Sugar cane, Japanese, as a forage crop.

Velvet beans, varieties for seed and for hay.

Vetches, varieties.

Vetches, best mixtures.

Wheat, breeding experiments.

Wheat, varieties.

In the Division of Soils a bulletin (No. 191) has been prepared and published by Professor M. J. Funchess giving the results of some of his experiments relative to soil toxins. The work of Professor Funchess along this line is now being supplemented by the Botanist of the Station, who is studying the decomposition of the toxins. Professor Funchess is also continuing his study of changes in the nitrates and other soluble constituents of the soil under various conditions.

#### LOCAL EXPERIMENT WORK WITH FIELD CROPS THROUGHOUT THE STATE.

Experimental work, (supported by a State appropriation) intended to throw light on the adaptability of special varieties to the different soils and climatic conditions in the different parts of the State has been conducted in every county. Fer-



fertilizer experiments have been made with the principal field crops in a large number of counties.

The impossibility of securing an adequate supply of potash, and the high cost of this fertilizer constituent, has made it necessary to reduce somewhat the number of fertilizer experiments with cotton.

It should be borne in mind that the departments of the Experiment Station doing local experiment work in the various counties of the State are Agriculture, Horticulture, Animal Husbandry, Entomology, Plant Pathology and Agricultural Engineering. The work of all of these is discussed in a separate publication constituting an annual report of the local experimental work of this Station.

Respectfully submitted,

J. F. DUGGAR,

Director of Experiment Station.

## REPORT OF BOTANIST.

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W. J. ROBBINS.

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Prof. J. F. Duggar, Director,  
Alabama Experiment Station,  
Auburn, Alabama.

Sir:

1. Under the Soils Toxin Project, which is carried on under the Adams Fund, I can report the following results: The cause of the disappearance of Vanillin, Cumarin, Pyridine and Quinoline in the soil has been found to be due to the action of bacteria. It is believed that the bacteria concerned in the disappearance of these compounds are more or less specific for each of them.

We have also found that guanidine carbonate, which is toxic at very weak concentrations to higher plants in water culture, is readily used as a source of nitrogen by many of the soil fungi. The compound appears to be absorbed and used as such but with the autolysis of the fungi the nitrogen in it appears as ammonia.

2. Some progress has also been made under the Hatch Fund in a preliminary study of the factors affecting cellulose digestion in fungi. This work is undertaken with the ultimate view of studying the causes of resistance of many plants to disease.

3. The list of Station projects are:

- (1) Soils Toxin project, Adams Fund.
- (2) Miscellaneous Botanical Investigations, Hatch Fund.

Respectfully submitted,

WILLIAM J. ROBBINS,  
Botanist.

## REPORT OF PLANT PATHOLOGIST.

---

G. L. PELTIER.

---

Prof. J. F. Duggar, Director,  
Agricultural Experiment Station,  
Auburn, Alabama.

Sir:

I am herewith submitting a brief statement relative to the Adams Fund project in the Department of Plant Pathology since my appointment September 1.

The one project we are working on under this Fund is a study of Citrus Canker. The work of the past few months has been devoted mainly to one phase of the life history of the organism. We are attempting to find whether the organism winters over in the soil on diseased fallen leaves or on diseased leaves on the trees. Not enough time has been devoted to this subject to give any definite information.

The work this coming season will be devoted to the many unknown points which occur in the life of the Citrus Canker organism. A start will be made in an attempt to find a resistant stock that will supercede Citrus Trifoliata, which is rather susceptible to Citrus Canker, now used entirely as stock for the Satsuma Grower.

Respectfully submitted,

GEO. L. PELTIER,  
Plant Pathologist.

## REPORT OF ASSOCIATE HORTICULTURIST.

---

J. C. C. PRICE.

---

Professor J. F. Duggar, Director,  
Experiment Station,  
Auburn, Alabama.

Sir:

I hereby submit report of the work under way in the Department of Horticulture for the year 1916. Professor Ernest Walker was head of the Department until September first, at which time he resigned, and I have had charge of the work only from that date until the present time.

The experimental work being conducted by this department is as follows:

Apples: Bloom notes and notes on yields of apples were continued, but since there are but few trees in the orchard, and only six of any one variety, the yield notes do not possess much of value.

Peaches: We continued our bloom notes, yield notes and notes on disease resistance for about twenty varieties for home and commercial use. Some excellent data have been secured. We have under way some pruning experiments to determine the relative effect of winter and summer pruning.

Pecans: Twelve varieties are now growing on the Station grounds that promise good results. We are comparing different methods of grafting and budding of the pecan, with indications that valuable results will be secured.

Pears: An experiment which has been running for a number of years to note the result of the use of potash as a preventive of "fire blight" is still being carried on, but owing to the scarcity of potash it seems that we may have to abandon this for the incoming year. We have planted a variety pear orchard consisting of eighteen of the leading varieties. A part of these trees should yield their first crop in 1917.

Grapes: Our variety vineyard was planted to test variety adaptability and disease resistance of this fruit. It gives promise of excellent results. The early freeze of the present



winter has damaged the vines considerably, but what the final damage will prove to be is problematical.

Vegetables: We are still continuing our variety and fertilization tests on tomatoes. We have also similar experiments under way with sweet potatoes as well as experiments in tuber selection, methods of bedding, vines vs. slips for late planting, and storage with a view of obtaining data on the keeping qualities of all varieties used in these tests. Variety tests were continued with sweet corn, peppers, okra, egg plant and cucumber. We are also continuing our work on the winter forcing of lettuce in cold frames with varieties and fertilizer tests of the same. We are also continuing our forcing of tomatoes in the greenhouse as well as work in the greenhouse with carnations and chrysanthemums.

The above is in addition to the Local Experiment work, conducted in a number of counties and separately reported.

Respectfully submitted,

J. C. C. PRICE,

Associate Horticulturist.

## REPORT OF ENTOMOLOGIST.

---

W. E. HINDS.

---

Prof. J. F. Duggar,  
Auburn, Alabama.

Sir:

Regarding Entomological projects in 1916, I would report as follows:

### ADAMS FUND PROJECTS.

1. Rice Weevil Investigations: This project has received principal attention during the past year and substantial progress has been made. It is planned to embody the principal results in a bulletin which may be issued within the next few months. After the final study of the notes is made for this publication, we can tell better whether the project will call for further attention during the season of 1917.

2. Arsenate of Lead Investigations: The work on this project during the past season has added much data both in the field and in the laboratory. Co-operation on the chemical analytical work has been arranged with Dr. J. T. Anderson of this Station. The project is not yet completed.

### OTHER ENTOMOLOGICAL PROJECTS.

1. Mexican Cotton Boll Weevil: The advance of this important cotton pest has been followed for the season 1916, and it now occurs in every county in Alabama. A small area in the extreme northeastern corner of the State remains unfested as yet. Some study has been made of life history, parasites, methods of stalk destruction, etc. Boll weevil work has been done under Local Experiment Fund.

2. Green Plant Bug (*Nezara viridula*): This pest has been steadily increasing in abundance during the past three years, and in the southeastern counties of Alabama has become a pest of extreme importance. It occurs in small numbers to the northern edge of the State. It attacks a very large variety of garden and field crops, and in some sections appears to be a much more serious pest than is the boll weevil. Considerable study has been given to this pest during the fall months of 1916 under Local Experiment Fund.

As this pest has not been studied extensively by any station or by the U. S. Bureau of Entomology, and promises to be of prime importance particularly in the territory where cotton production is most severely affected by the boll weevil, it is quite possible that we shall desire to make this an Adams Fund project in 1917, taking the place of the Rice Weevil project, which may then be considered completed.

3. Argentine Ant: This important pest has become established at several points in Alabama, and has received considerable attention during 1916, particularly at Montgomery and Letohatchee. It is certain to command increasing attention in the future. This work has been done under Local Experiment Fund.

The publication work of the Department during 1916 has been as follows:

Bulletin No. 188: Boll Weevil In Alabama.

Press Bulletin No. 83: Controlling the Boll Weevil by Collecting Weevils and Infested Squares.

The Department has contributed to Plate Service, and has also published numerous articles in daily and weekly newspapers and in special Agricultural Journals.

The extension correspondence work of the year has required approximately 1100 dictated letters, and a large number of circular letters together with about 450 bulletins.

Respectfully submitted,

W. E. HINDS,

Entomologist.

## REPORT OF ANIMAL HUSBANDMAN.

---

G. S. TEMPLETON.

---

Prof. J. F. Duggar, Director,  
Alabama Experiment Station,  
Auburn, Alabama.

Sir:

I respectfully submit the following report of experimental work in the Animal Husbandry Department for the year 1916:

The experimental work conducted at Auburn, Alabama, is supported by the Hatch and Adams funds, appropriated by Congress. The experimental work in Marengo, Mobile and Dale counties is supported by the State appropriation provided by the Local Experiment Law. The experiments with the various classes of live stock are as follows:

### BEEF CATTLE.

The co-operative steer feeding experiments started at Allenville, Marengo County, Alabama, two years ago were continued during the year. Forty-five steers are now on feed at Allenville, divided into three lots and fed as follows:

Lot 1—Velvet beans and corn silage.

Lot 2—Cottonseed meal and corn silage.

Lot 3—Cottonseed meal and sorghum silage.

An experiment was conducted during the past summer with the view of determining the relative carrying capacity of some of the pasture grasses adapted to the lime lands of West Alabama. The three grasses compared in this experiment were Bermuda, Paspalum and Johnson grass. This experiment will be repeated the coming summer.

The breeding herd of 450 head of pure bred and grade Herefords is now used in experiment. The herd is divided into several lots with the view of testing the different methods of wintering cattle of various ages, and determining the cost of producing feeder steers.

### DAIRY CATTLE.

The dairy cattle projects at Auburn, Alabama, under way during the year were as follows:



First, a study of the relative feeding value of ground velvet beans in the pod and cottonseed meal as part of the ration for milk and butter fat production.

Second, a study of the influence of the above feeds on the quality of butter.

Third, a comparison of skim milk, Blatchford's Calf Meal and oat meal as a feed for rearing dairy calves up to sixteen weeks of age.

#### SWINE.

The experimental work at Auburn, Alabama, in co-operation with the Department of Chemistry to determine the influence of some southern feeds upon the properties (melting point, iodine value, keeping quality and color) of lards, is still in progress.

The experimental work at Ozark, Dale County, Alabama, was continued throughout the year. The experiments under way on this farm were planned with the view of determining the cost of producing pork under average farm conditions, and studying the relative feeding value of crops typical of that section for producing pork.

#### POULTRY.

The experimental work at Citronelle, Mobile County, Alabama, was continued throughout the year. Several feeds are being studied as to their relative efficiency and economy in egg production.

Two new features were added to this work during the year:

First, to determine the influence of selection on the egg production of the flock.

Second, to determine the best age to market poultry.

Respectfully submitted,

GEO. S. TEMPLETON,

Animal Husbandman.

## REPORT OF VETERINARIAN.

---

C. A. CARY.

---

Prof. J. F. Duggar, Director,  
Alabama Experiment Station,  
Auburn, Alabama.

Sir:

During 1916 the following lines of work were conducted:

Tests were made to determine the internal toxic effects of *Robina pseudacacia*, *Lolium temulentum* and *Rhus toxicodendron*.

We also repeated tests on the toxic effects of china berries on pigs.

Some observations were made on the effects of peanuts upon the ovaries of sows. This work will be investigated more extensively in 1917.

Some tests were made on the internal effects of nitrate of soda on dogs and cats.

An attempt has been made to find the eggs of *Sclerostoma pinguicola* in the urine or bladder of pigs infested with that parasite.

Records of the kinds and frequency of the various animal parasites in chickens, pigs and cattle have been continued.

A press bulletin was issued on hog cholera. It gave a brief outline of the cause, symptoms, post mortem lesions, methods of spreading and preventing the disease.

On account of the extremely wet weather in July and early August the Summer Series of Farmers Institutes were cut short. In fact all the Institutes were held prior to the rainy season.

|                                 |     |
|---------------------------------|-----|
| Number of Institutes Held ..... | 12  |
| Average Attendance .....        | 53  |
| Total Attendance .....          | 637 |

The Summer School for Farmers was held at Auburn July 29th to August 5th, in the middle of the rainy season.

Notwithstanding the unfavorable weather conditions, there were 734 in attendance, and a large number of the Counties of the State were represented. While the attendance was

somewhat less than the previous year, the lectures and demonstrations were very valuable to the farmers of the State.

Respectfully submitted,

C. A. CARY,

Veterinarian.

# REPORT OF CHEMIST OF SOILS AND CROP INVESTIGATIONS.

---

J. T. ANDERSON.

---

Prof. J. F. Duggar, Director,  
Alabama Agricultural Experiment Station,  
Auburn, Alabama.

Sir:

The following condensed statement of the work of this department for the year 1916, is respectfully submitted:

1. Adams Project: Soil Requirements by Plant Analysis. Hitherto the work on this project has been limited to Potash in the Cotton Plant. As this narrowed down, the analytical work has been completed, and the manuscript will soon be ready for the printer.

It was decided to extend the scope of the work so as to include both phosphoric acid and potash and use the turnip as the plant for investigation. Three different types of soil were selected for the study, and imbedded cylinders were used as containers. The same system of fertilization was used as with the cotton plant, using the three fertilizer constituents alone and in their several combinations.

2. Adams Project: Arsenate of Lead as an Insecticide. This work was done in co-operation with the Department of Entomology, only the chemical analysis being done by this department.

3. Miscellaneous. Under this head is included all the chemical work for the other departments of the Station, as well as for individual citizens of the State, and embraces the chemical analysis of corn, hays and other crops used in experimentation, soils, etc.

Respectfully submitted,  
JAMES T. ANDERSON,  
Chemist, Soils and Crops Investigations.



# REPORT OF PHYSIOLOGICAL CHEMIST.

---

C. L. HARE.

---

Prof. J. F. Duggar, Director,  
Alabama Experiment Station,  
Auburn, Alabama.

Sir:

Herewith I submit a report of the investigations of the Physiological Chemist:

During the year 1916 the work of this department in general outline has been along the same lines that have been pursued for several years.

Experiments in breeding cotton with seed with continuous high oil content from year to year, shows promising positive results.

One or two strains of cotton have maintained a high average percentage of oil in seed throughout the breeding experiments, even during years when the amount of oil in cotton seed generally was below the yearly averages.

The results secured in breeding for cotton seed of high protein content seem to promise some measure of success.

Experiments designed to show the effect of different kinds of fertilizers upon the percentages of oil, protein and mineral constituents, in cotton seed, indicate that the quantities of these constituents are not materially effected by the difference in fertilizers used, although the numbers of analyses made to date are not sufficient to prove the indications.

Determinations of the more important mineral constituents in cotton seed have so far failed to show any definite relationship between the percentages of these constituents and the oil and protein content of the seed.

The analyses of lard from hogs from nine feeding experiments were made during the year, showing some interesting points, of the effects of some common fat producing feeds upon the lard.

The following experiments are now in process:

A study of the lard produced by feeding the following:

1. Corn alone.

2. Velvet bean meal alone.
3. Corn one half and velvet bean meal one half.
4. Velvet bean and pod meal.
5. Peanut meal one half and corn one half.
6. Peanuts one half and corn one half.

Respectfully submitted,

C. L. HARE,  
Physiological Chemist.





BULLETIN No. 193

FEBRUARY, 1917

**ALABAMA**

**Agricultural Experiment Station**

OF THE

**Alabama Polytechnic Institute**

**AUBURN**

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**PEANUTS**

**Tests of Varieties and Fertilizers**

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By

J. F. DUGGAR,  
E. F. CAUTHEN,  
J. T. WILLIAMSON,  
O. H. SELLERS.

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1917  
Post Publishing Company  
Opelika, Ala.



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 F. W. Wendt, Assistant.  
 A. E. Hayes, Assistant.

### AGRICULTURAL ENGINEERING:

R. U. Blasingame, Agricul-  
 tural Engineer.

# PEANUTS—TESTS OF VARIETIES AND FERTILIZERS

By  
J. F. DUGGAR,  
E. F. CAUTHEN,  
J. T. WILLIAMSON,  
O. H. SELLERS.

## SUMMARY.

The average yield of unshelled peanuts obtained from regular variety tests, made in different parts of the State and covering a period of five years, ranged from 871 pounds of McGovern to 1244 pounds of Red Spanish per acre. Taking the yield of Red Spanish as a basis (100 percent), the percentage yield of the different varieties averaged as follows:

|                     |     |                             |    |
|---------------------|-----|-----------------------------|----|
| Red Spanish .....   | 100 | Tennessee Red .....         | 86 |
| Valencia .....      | 91  | Virginia Bunch .....        | 86 |
| White Spanish ..... | 88  | Virginia Runner .....       | 85 |
| McGovern .....      | 87  | North Carolina Runner ..... | 84 |

The average percentage of shelled nuts or "meats" of each variety, obtained by carefully weighing and hand-shelling a given amount of dry unshelled peanuts, shows a remarkably wide variation, from 39.3 percent in Jumbo to 75.1 percent in White Spanish. The true commercial value of the crop of an acre is based, not on the number of pounds of unhulled peanuts, but on the number of pounds of "meats" produced.

The common varieties of peanuts are divided into two great classes—those having an upright or bunch habit of growth, and those having a low spreading or running habit. To the bunch varieties belong the White Spanish, Red Spanish, Valencia, Virginia Bunch, and Tennessee Red. Among the running varieties are the North Carolina or African, Virginia Runner, McGovern, and the Running Jumbo.

In a number of experiments (Table IV) there were found great differences in the weight of single unshelled peanuts, of "peas" of different varieties, and the average percentage of sound "peas" per pod. The heaviest unshelled peanuts were the Tennessee Red

(246 pods to the pound), and the lightest, the White Spanish (461 pods to the pound).

Based on the average percentage of sound nuts of each variety and of its oil content, the varieties arranged according to the number of pounds of oil produced per ton take the following rank: White Spanish 702 pounds, Red Spanish 693 pounds, Valencia 572 pounds, McGovern 548 pounds, Tennessee Red 527 pounds, North Carolina Runner 524 pounds, Virginia Runner 493 pounds, and Jumbo 354 pounds.

The average yield of unshelled peanuts as reported by Alabama oil mills, is estimated at 850 pounds per acre. From a ton of Spanish peanuts the mills obtain from 600 to 700 pounds of oil, and from 1200 to 1300 pounds of peanut cake. All the oil mills reporting preferred the White Spanish variety, except one mill which preferred the North Carolina Runner because it is claimed that the yield of the latter per acre is in excess of the other varieties.

From many complete fertilizer tests with peanuts, located in different parts of the State and covering a period of six years, it is concluded:

1. That acid phosphate at the rate of 200 to 300 pounds per acre produced a profitable increase in peanuts grown on sandy and other soils that are well adapted to this crop;

2. That potash applied in the form of kainit at the rate of 100 and 200 pounds per acre did not always prove profitable, except in a few experiments located on infertile sandy soil;

3. That slaked lime at the rate of 600 pounds per acre made a profitable increase in yield when applied on sandy soil;

4. That cottonseed meal as a source of nitrogen did not give profitable increases in yield, and is, therefore, not to be generally recommended for this leguminous crop.

The average yield of peanut straw (vines after removal of peanuts) from four experiments varied from 2316 pounds of North Carolina Runner, to 1234 pounds of Virginia Bunch per acre. The average percent of dried unhulled peanuts to the weight of the whole plant ranged from 32 percent in North Carolina Runner, to 39 percent in Red Spanish.

## INTRODUCTION.

The peanut industry is growing rapidly in Alabama. This rapid growth is coming as a result of the crop diversification campaigns, the change from the one crop system of cotton due to the invasion of the Mexican cotton boll weevil, and the growing demand for peanut oil and cake for stock feed and fertilizer.

In soil and climate Alabama is well adapted to peanuts. Its cottonseed oil mills are being converted into peanut mills to manufacture oil and cake. The farmer has most of the implements on hand needed for the planting and culture of this crop. The additional equipment most needed is a custom picker for each community that grows any considerable amount of peanuts.

## VARIETY TESTS OF PEANUTS.

Table I shows that the yields of a variety differ widely in different years and in different localities. This variation may be due to seasonal differences, time of planting, character of soil, fertilizer or cultivation.

Some of the experiments were made on the Experiment Farm at Auburn. Most of them were made on farms scattered throughout the State. These latter tests constituted part of the work conducted under the provisions of the Local Experiment Law. Each experiment made away from Auburn was planned and supervised by a Station representative. The soil, fertilizer and cultural treatment for each variety in any particular experiment was the same. The same strains of seed peanuts were supplied to every experimenter making variety experiments in a given year. The experimenter or a representative of the Station harvested plots of uniform size and reported the weight of the nuts after they had been thoroughly dried.

The time of the planting of the different experiments ranged from April 26 to June 27. It may be of interest to note that the largest yields came from plantings made between May 1 and June 15.

In all cases, the experiments were located on some type of sandy soil, ranging from sandy loam, with clay subsoil, to fine sand. A complete commercial fertilizer was used under nearly all the experiments.

TABLE I. Yield of Varieties of Peanuts in Different Localities and Years; in Pounds of Unhulled and Hulled Nuts Per Acre.

| VARIETY                           | W. E. Clarke,<br>Pinckard, 1911 | T. E. Helms,<br>Honora ville, 1912 | T. W. Jockish,<br>Greensboro, 1912 | D. B. Lewis,<br>Jasper, 1914 | D. B. Lewis,<br>Jasper, 1915 | I. O. O. F. Home,<br>Cullman, 1915 | E. A. Simmons,<br>Greenville, 1915 | D. B. Lewis,<br>Jasper, 1916 | I. O. O. F. Home,<br>Cullman, 1916 | W. M. Dean,<br>Auburn, 1916 | E. A. Simmons,<br>Greenville, 1916 | H. J. Dudley,<br>Seale, 1916 | Experiment Station,<br>Auburn, 1916 | Average unhulled<br>nuts | Average, meats |
|-----------------------------------|---------------------------------|------------------------------------|------------------------------------|------------------------------|------------------------------|------------------------------------|------------------------------------|------------------------------|------------------------------------|-----------------------------|------------------------------------|------------------------------|-------------------------------------|--------------------------|----------------|
| Virginia Bunch                    | Unhulled<br>{ Meats 591         | Lbs. 1344                          | Lbs. 1174                          | Lbs. 1126                    | Lbs. 2310                    | Lbs. 1190                          | Lbs. 388                           | Lbs. 137                     | Lbs. 1146                          | Lbs. 1604                   | Lbs. 784                           | Lbs. 512                     | Lbs. 816                            | Lbs. 1519                | Lbs. 561       |
| Red Spanish                       | Unhulled<br>{ Meats 1084        | Lbs. 1066                          | Lbs. 1344                          | Lbs. 2080                    | Lbs. 2310                    | Lbs. 1527                          | Lbs. 386                           | Lbs. 832                     | Lbs. 1271                          | Lbs. 784                    | Lbs. 378                           | Lbs. 623                     | Lbs. 1352                           | Lbs. 1244                | Lbs. 960       |
| White Spanish                     | Unhulled<br>{ Meats 532         | Lbs. 1422                          | Lbs. 1056                          | Lbs. 1558                    | Lbs. 2310                    | Lbs. 1760                          | Lbs. 354                           | Lbs. 707                     | Lbs. 1412                          | Lbs. 980                    | Lbs. 598                           | Lbs. 843                     | Lbs. 531                            | Lbs. 1094                | Lbs. 935       |
| Tennessee Red                     | Unhulled<br>{ Meats 867         | Lbs. 1363                          | Lbs. 1008                          | Lbs. 780                     | Lbs. 1500                    | Lbs. 1500                          | Lbs. 486                           | Lbs. 994                     | Lbs. 1520                          | Lbs. 1421                   | Lbs. 683                           | Lbs. 1072                    | Lbs. 1272                           | Lbs. 1052                | Lbs. 645       |
| Valencia                          | Unhulled<br>{ Meats 355         | Lbs. 1363                          | Lbs. 1008                          | Lbs. 544                     | Lbs. 1850                    | Lbs. 2208                          | Lbs. 336                           | Lbs. 651                     | Lbs. 1536                          | Lbs. 1421                   | Lbs. 683                           | Lbs. 1008                    | Lbs. 1219                           | Lbs. 1091                | Lbs. 674       |
| Jumbo                             | Unhulled<br>{ Meats 591         | Lbs. 1303*                         | Lbs. 1536                          | Lbs. 1024                    | Lbs. 1530                    | Lbs. 206                           | Lbs. 206                           | Lbs. 410                     | Lbs. 1061                          | Lbs. 784                    | Lbs. 415                           | Lbs. 912                     | Lbs. 1164                           | Lbs. 1143                | Lbs. 242       |
| N. C. Runner (or Grey<br>African) | Unhulled<br>{ Meats 946         | Lbs. 1185                          | Lbs. 1008                          | Lbs. 1750                    | Lbs. 1921                    | Lbs. 411                           | Lbs. 435                           | Lbs. 1451                    | Lbs. 1029                          | Lbs. 784                    | Lbs. 415                           | Lbs. 912                     | Lbs. 1164                           | Lbs. 1064                | Lbs. 562       |
| Virginia Runner or<br>Large Red   | Unhulled<br>{ Meats 1241        | Lbs. 1126**                        | Lbs. 1152                          | Lbs. 1226                    | Lbs. 1366                    | Lbs. 470                           | Lbs. 193                           | Lbs. 827                     | Lbs. 1029                          | Lbs. 784                    | Lbs. 415                           | Lbs. 912                     | Lbs. 1164                           | Lbs. 1087                | Lbs. 576       |
| Jumbo (Running)                   | Unhulled<br>{ Meats 931         | Lbs. 948                           | Lbs. 1680                          | Lbs. 1300                    | Lbs. 1584                    | Lbs. 448                           | Lbs. 202                           | Lbs. 237                     | Lbs. 140                           | Lbs. 784                    | Lbs. 415                           | Lbs. 912                     | Lbs. 1164                           | Lbs. 1192                | Lbs. 353       |
| McGovern                          | Unhulled<br>{ Meats 1241        | Lbs. 948                           | Lbs. 1680                          | Lbs. 1300                    | Lbs. 1584                    | Lbs. 448                           | Lbs. 202                           | Lbs. 237                     | Lbs. 140                           | Lbs. 784                    | Lbs. 415                           | Lbs. 912                     | Lbs. 1164                           | Lbs. 871                 | Lbs. 421       |

† Leaf spot reduced yield.

\* Bought under name of "Bunch Jumbo."

\*\* Bought under name of "Large Red."



Table I shows the relative yield of dry, unhulled peanuts and meats or kernels per acre, but does not show their commercial value. The unhulled dry nuts of some of the varieties have 60 percent of hulls and pops, while others like the White Spanish, have only 25 percent. The true value of an acre is found only by multiplying the number of pounds of peanuts made on an acre by the percent of meats or kernels of that particular variety. Particular attention is called to the figures in the last column of Table II, which shows the average percentage of meats obtained in experiments extending through three years.

#### RELATIVE YIELDS OF VARIETIES.

The preceding table (Page 6), taken as a whole, conveys but little meaning, yet when dissected, as below, the results throw considerable light on the relative yields of varieties as measured in the weight of dried and unhulled nuts.

For comparison, the yield of *unhulled nuts* of Red Spanish is taken as a basis, and hence this yield is rated at 100 percent. Then each variety is compared with the Red Spanish, but only in those years in which the compared variety and the Red Spanish were both tested along side. The results are given below:

In 7 out of 12 experiments Red Spanish proved superior in yield to White Spanish.

|                                                            | <i>Pounds<br/>per Acre</i> | <i>Relative<br/>Yield</i> |
|------------------------------------------------------------|----------------------------|---------------------------|
| White Spanish -----                                        | 1094                       | 88                        |
| Red Spanish -----                                          | 1244                       | 100                       |
| In 7 out of 12 tests Valencia was exceeded by Red Spanish: |                            |                           |
| Valencia -----                                             | 1137                       | 91                        |
| Red Spanish -----                                          | 1244                       | 100                       |

In 8 out of 10 experiments North Carolina Running was equalled, or exceeded in yield of unhulled nuts by Red Spanish:

|                             |      |     |
|-----------------------------|------|-----|
| North Carolina Runner ----- | 1068 | 84  |
| Red Spanish -----           | 1268 | 100 |

In 6 out of 10 tests Virginia Runner was surpassed in yield of unhulled nuts by Red Spanish:

|                       |      |     |
|-----------------------|------|-----|
| Virginia Runner ----- | 1087 | 85  |
| Red Spanish -----     | 1275 | 100 |

The comparison is still more unfavorable to Virginia Runner on the basis of pounds of meats per acre,

since in a number of the tests this variety had a large proportion of pops. The four localities in which Virginia Runner exceeded Red Spanish in yield of unhulled nuts were Pinckard, Dale County; Honoraville, Butler County; Jasper, Walker County; and Auburn, Lee County. In only one of the six tests (Pinckard) did Virginia Runner afford a larger weight of *meats* per acre.

In 3 out of 5 tests McGovern was exceeded in yield of unhulled nuts by Red Spanish, and in every year in which the meats were separated Red Spanish afforded a larger weight of meats per acre:

|                   |      |     |
|-------------------|------|-----|
| McGovern .....    | 871  | 87  |
| Red Spanish ..... | 1005 | 100 |

In 6 out of 9 experiments Tennessee Red was surpassed by Red Spanish on the basis of unhulled nuts:

|                     |      |     |
|---------------------|------|-----|
| Tennessee Red ..... | 1079 | 86  |
| Red Spanish .....   | 1252 | 100 |

In all experiments, except one, the yield of meats from Red Spanish was greater than the yield from Tennessee Red.

In 4 out of 6 tests Virginia Bunch was exceeded in yield of unhulled nuts by Red Spanish:

|                      |      |     |
|----------------------|------|-----|
| Virginia Bunch ..... | 1193 | 86  |
| Red Spanish .....    | 1397 | 100 |

In every case where the meats were separated Red Spanish afforded a larger yield of meats per acre than did Virginia Bunch.

#### SOUND KERNELS (MEATS) IN UNHULLED DRY PEANUTS.

Table II shows the percent of sound kernels or meats for each variety as grown in different tests in various parts of the State. A given amount of dried peanuts without selection was taken from each variety and carefully weighed and hand shelled. The sound kernels were weighed and the percentage of kernels or meats calculated.

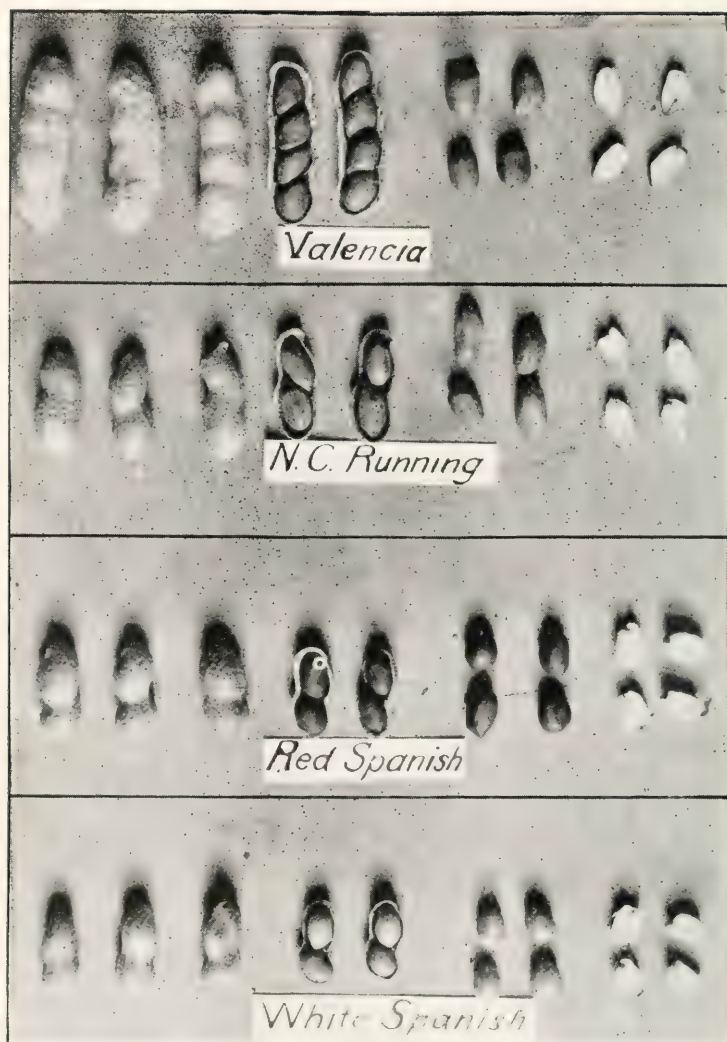


Fig. 1. North Carolina Runner, showing its spreading habit of growth and peanuts clinging along its stem.



Fig. 2. White Spanish, showing the upright habit of growth of plant; the clustering of the peanuts about the base of the stems, and spots of disease on some of its leaves.

PLATE II



Plates II and III show eight common varieties of peanuts.  
The figures are reduced to about half size.









Fig. 3 One method of planting peanuts. A row of peanuts growing in the wide corn middle.

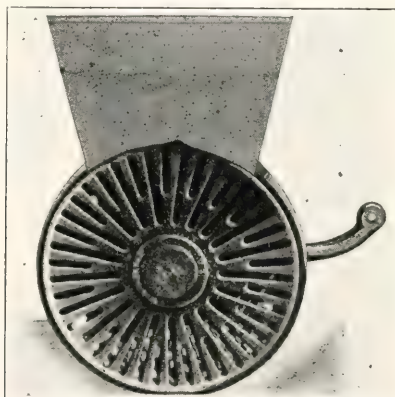


Fig. 4. Peanut huller. A simple coffee mill-like machine that hulls one pound per minute.

TABLE II. *Per Cent of Sound Kernels (Meats) in Unhulled Dry Peanuts.*

| VARIETY         | Location of Each Experiment       |                                 |                              |                              |                                    |                                    |                                    |                                     |                         |
|-----------------|-----------------------------------|---------------------------------|------------------------------|------------------------------|------------------------------------|------------------------------------|------------------------------------|-------------------------------------|-------------------------|
|                 | J. E. Helms,<br>Honoraville, 1911 | W. E. Clarke,<br>Pinckard, 1911 | H. J. Dudley,<br>Seale, 1916 | D. B. Lewis,<br>Jasper, 1916 | I. O. O. F. Home,<br>Cullman, 1916 | E. A. Simmons,<br>Greenville, 1915 | I. O. O. F. Home,<br>Cullman, 1915 | Experiment Station,<br>Auburn, 1916 | Average of<br>all tests |
| Virginia Runner | %                                 | 75.0                            | 49.9                         | 57.0                         |                                    | 44.4                               | 34.4                               | 59.3                                | 53.3                    |
| Tennessee Red   |                                   | 65.0                            | 60.7                         | 55.9                         | 67.5                               | 38.1                               | 60.2                               | 50.5                                | 56.9                    |
| N. C. Runner    | 71.2                              | 73.0                            | 63.9                         |                              |                                    | 68.4                               | 21.4                               | 48.2                                | 57.7                    |
| Virginia Bunch  |                                   | 58.0                            | 47.5                         |                              |                                    | 35.4                               | 51.5                               | 37.7                                | 46.0                    |
| McGovern        |                                   |                                 | 60.5                         | 59.0                         |                                    |                                    |                                    | 50.5                                | 56.6                    |
| Valencia        | 54.0                              | 34.0                            | 64.2                         | 63.0                         | 69.1                               | 61.3                               | 69.3                               | 60.7                                | 59.5                    |
| Red Spanish     | 68.8                              | 67.0                            | 76.4                         | 72.6                         | 76.4                               | 65.6                               | 73.4                               | 76.5                                | 72.1                    |
| White Spanish   |                                   |                                 | 77.5                         | 77.4                         | 78.1                               | 69.1                               | 76.2                               | 72.4                                | 75.1                    |
| Jumbo           |                                   | 41.0                            |                              |                              |                                    | 45.1                               | 31.8                               |                                     | 39.3                    |

In the column of averages, it is noticed that the percentages of meats of the different varieties range from 75.1 percent in the White Spanish to 39.3 percent in the Jumbo. On this basis, a ton of unhulled Jumbo peanuts yields 786 pounds of meats, while a like amount of White Spanish affords 1502 pounds. The amount of waste in the form of hulls, pops and immature peas varies widely in the different varieties. The commercial value of peanuts is based largely on the amount of meats yielded by a ton of unhulled nuts. Hence oil mills can afford to pay a higher price for varieties having a high percentage of meats (as the Red Spanish and White Spanish) than for most of the running varieties.

The percentage of meats of a variety varies with season and soil. For example, in 1911, at Pinckard, Dale County, Virginia Runner shelled out 75 percent of meats; at Cullman, Cullman County, in 1915, it gave only 34.4 percent meats, showing the effect of seasons, soil, locality and other factors.

In the same year, the percentage of sound meats of a variety differs when grown in different parts of the State. Tennessee Red was grown in 1916 in Russell, Walker, Cullman and Lee Counties, and showed a va-

riation from 67.5 percent of meats in Cullman to 50.5 percent in Lee.

By grouping the tests into northern and southern divisions and taking averages, the following results are obtained:

TABLE III. *Average Percentage of Sound Nuts (Meats) in Unhulled Peanuts Grown in South Alabama and in North Alabama.*

|                       | South:<br>Greenville<br>Honoraville<br>Pinckard<br>Seale<br>Auburn | No.<br>tests | North:<br>Cullman<br>Jasper<br>Cullman | No.<br>tests |
|-----------------------|--------------------------------------------------------------------|--------------|----------------------------------------|--------------|
|                       | <i>Percent.</i>                                                    |              | <i>Percent.</i>                        |              |
| Virginia Runner ----- | 57.2                                                               | 1            | 45.7                                   | 2            |
| Tennessee Red -----   | 53.7                                                               | 4            | 61.5                                   | 3            |
| N. C. Runner -----    | 64.9                                                               | 5            |                                        |              |
| Virginia Bunch -----  | 55.5                                                               | 2            | 59.0                                   | 1            |
| Valencia -----        | 54.8                                                               | 5            | 67.1                                   | 3            |
| Red Spanish -----     | 70.8                                                               | 5            | 74.1                                   | 3            |
| White Spanish -----   | 73.0                                                               | 3            | 77.2                                   | 3            |
| Jumbo -----           | 43.5                                                               | 2            |                                        |              |

It is noticed that some varieties yield a higher percentage of meats in one section of the State than they do in another section. This difference may be due in part to the longer time required by some varieties to grow and mature. The running varieties, like North Carolina and Tennessee Red, which are late, have in these experiments averaged a larger percent of meats when grown in the southern than in the northern section, while the Spanish varieties, which are early, and also the Valencia, have in these tests shelled out a larger percent of sound peas in the northern than in the southern section.

#### DESCRIPTION OF VARIETIES OF PEANUTS.

The many different names used both for distinct varieties and for those whose characters do not mark them as distinct are confusing. It is unfortunate that some seedsmen and farmers, zealous to sell seed, should attach new names to old varieties, and thereby confuse and mislead the buyer. There is no objection to a grower attaching some distinguishing mark to a greatly improved strain or to a distinctly new variety, but it should be shown that he has improved the old variety or found a distinctly new one. If the originator would tell the true source of his improved strain or

the origin of his new variety, this knowledge would help the farmer to appreciate more fully the characters for which the new strain or variety is notable. A name should distinguish the variety from other varieties. The great number of variety names, without distinguishing characters, is a source of much confusion.

The common varieties of peanuts may be divided into two great classes; those having an upright, bunchy habit of growth, and those having a low spreading or "running" habit.

Among the common varieties of the first group are the White Spanish, Red Spanish, Valencia, Virginia Bunch and Tennessee Red. Those having the spreading habit are North Carolina, sometimes called African, Virginia Runner and McGovern. In this division may also be included one of the varieties called Jumbo, which name is listed by some seedsmen as a bunch and by others as a runner.

*White Spanish.*—This variety has an erect habit of growth, is about 10 to 14 inches high when grown on average soil, is early, and grows an abundance of foliage. Its pods grow in a cluster about the base of the stems and adhere well to the vines when they are harvested.

The pods are small and require about 461 unshelled peanuts to weigh a pound. The peas vary in color from light pink to cream. The unhulled nuts yield 75.1 percent of meats. The average amount of oil contained in a ton (but not all capable of being extracted) is 702 pounds, which is more than the amount of oil found in a ton of any other variety. The pods of both Spanish varieties are assumed to weigh 30 pounds per bushel, though 28 pounds are sometimes sold as a bushel. This is probably the most productive variety.

*Red Spanish.*—This variety in habit of growth is very much like the White Spanish. Its pods are larger, 390 weighing a pound. It shells out about 72 percent of light, red nuts. The amount of oil per ton is 693 pounds, which is the second largest amount obtained.

*Valencia.*—This variety, sometimes called Improved Valencia, is erect in habit and grows from 12 to 24 inches high. Its pods grow close to its roots and cling poorly to the vines when they are pulled up.

The pods are medium in diameter and are long, with two, three or four peas crowded closely together.



About 266 pods weigh a pound. The peas are red and small, and form about 60 percent of the weight of the pods. In unshelled perfect pods the percentage of oil was 28.6, or 572 pounds per ton. A bushel weighs about 24 pounds.

*Virginia Bunch.*—This is a semi-erect variety. Its pods cluster about the base of the stems; they are bright, nearly smooth, and require about 283 to weigh a pound. They contain one, two and sometimes three pale or pinkish peas. The percentage of meats found in the unshelled pods was 46, and of oil 21.2. The total oil contained per ton of unshelled peanuts was only 424 pounds. The usual weight per bushel is 22 pounds.

*Tennessee Red.*—This variety resembles the Spanish varieties in type of plant. It is medium early, and its pods cling to the stems when they are pulled up. The pods have two or three peas, and about 246 unshelled peanuts are required to weigh a pound. It shells out 56 percent of meats. The peas are red. The percentage of oil in the unshelled pods is 23.6, or 527 pounds per ton. A bushel is usually assumed to weigh 22 pounds.

*North Carolina.*—This variety, sometimes called African or Wilmington, has a low spreading habit of growth. The variety called McGovern or Florida seems to be nearly the same as this, with probably this difference, that the McGovern seems to have more resistance to rotting of the nuts and to leaf spot. The stems of McGovern are long, slender and spreading.

The pods of the North Carolina are small, and do not cling well to the stems when the vines are pulled up. A pod usually has two small reddish peas. This variety is late. It required about 440 pods to weigh a pound, and yielded about 66 percent meats. The percentage of oil found was 26.2 percent, or 524 pounds in a ton of unshelled pods. A bushel is assumed to weigh 22 pounds.

*Virginia Runner.*—This variety is sometimes called Virginia Improved. It resembles, in habit of growth, the North Carolina or African variety, except that its pods are considerably larger. Its pods and peas, in size and color, closely resemble those of the Virginia Bunch variety; 279 pods weighed a pound, and yielded 53.1 percent of meats. This variety yields 24.6 percent of oil, or 493 pounds per ton.



*Jumbo*.—Under this name, seedsmen have listed a running Jumbo and a bunch Jumbo. The two resemble each other in every respect, except in habit of growth of vines. In habit of growth and size of pods these two forms closely resemble the Virginia Bunch and Virginia Runner. Of the Jumbo samples studied, 276 of the pods weighed a pound, and yielded only 41 percent of meats. It seems that the name Jumbo has been applied to large nuts, and does not represent a distinct variety. A Jumbo may be a Virginia Bunch or a Virginia Runner, or even a Tennessee Bunch.

The varieties grown under the name of Jumbo averaged lowest in oil, 17.7 per cent, or 354 pounds of oil in a ton of unshelled peanuts.

#### SIZE OF PEANUTS AND NUMBER OF PEAS PER POD.

Table IV shows the average number of unhulled peanuts and of sound peas required to weigh one pound; percentages by weight of sound peas in unhulled pods; and number of sound peas per pod, together with the maximum and minimum numbers. The averages are based on from 3 to 9 experiments made in 4 different years. The maximum and minimum numbers indicate that within each variety there is an extremely wide range in the size of nuts, number of peas per pod, and percentage of peas. These fluctuations are due apparently to variations in seasons, soils, etc. These figures are put on record as a part of the description of each variety.

TABLE IV. *Number of Peanuts Required to Make One Pound; Average Number Sound Nuts Per Pod; and Percent Sound Nuts Per Pod.*

| VARIETY          | No. Tests | No. Unshelled Nuts per Lb. |      |      | Number Sound Nuts per Lb. |      |      | Av. No. Sound Nuts per Pod |      |      | Per cent Sound Nuts Per Pod |      |      |
|------------------|-----------|----------------------------|------|------|---------------------------|------|------|----------------------------|------|------|-----------------------------|------|------|
|                  |           | AV.                        | MAX. | MIN. | AV.                       | MAX. | MIN. | AV.                        | MAX. | MIN. | AV.                         | MAX. | MIN. |
| Tennessee Red    | 9         | 246                        | 489  | 186  | 781                       | 984  | 730  | 1.88                       | 2.41 | 0.60 | 56.9                        | 67.5 | 38.1 |
| N. C. Runner     | 9         | 440                        | 498  | 349  | 943                       | 1080 | 854  | 1.34                       | 1.87 | 0.59 | 57.7                        | 73.0 | 21.4 |
| Virginia Bunch   | 6         | 283                        | 502  | 196  | 539                       | 647  | 526  | 0.90                       | 1.37 | 0.45 | 46.0                        | 58.0 | 35.4 |
| McGovern----     | 3         | 351                        | 399  | 315  | 871                       | 964  | 809  | 1.41                       | 1.57 | 1.20 | 56.6                        | 60.0 | 50.5 |
| Valencia-----    | 10        | 266                        | 409  | 211  | 854                       | 943  | 676  | 2.06                       | 2.90 | 0.65 | 59.5                        | 69.3 | 34.0 |
| Red Spanish----  | 9         | 390                        | 573  | 212  | 984                       | 1132 | 888  | 1.61                       | 1.93 | 1.09 | 72.1                        | 76.5 | 65.4 |
| White Spanish--- | 8         | 461                        | 689  | 460  | 1105                      | 1461 | 984  | 1.76                       | 1.91 | 1.48 | 75.1                        | 78.1 | 69.1 |
| Virginia Runner  | 7         | 279                        | 425  | 183  | 612                       | 888  | 482  | 1.12                       | 1.66 | 0.62 | 53.3                        | 75.0 | 34.4 |
| Jumbo-----       | 5         | 276                        | 423  | 224  | 559                       | 666  | 477  | 0.96                       | 1.68 | 0.67 | 39.3                        | 45.1 | 31.8 |

This table shows great differences in weight of single nuts and peas of different varieties, and in the number of peas per pod. Virginia Bunch yielded on an average in 6 tests only 46 percent of sound peas, which indicates the tendency of running varieties to produce pops when soil conditions are unfavorable. The White Spanish yielded 75.1 percent by weight of sound peas. This difference in yield is an important factor in determining the price that oil mills can afford to pay for nuts to crush.

The heaviest unhulled nuts are found in the Tennessee Red variety (246 pods to the pound). The lightest unhulled nuts are in the White Spanish (461 pods to the pound), which are considerably smaller than those of the Red Spanish. Virginia Bunch, closely followed by Jumbo and Virginia Runner, produce the heaviest shelled peas—if we take no account of the pops, or defective peas.

#### RELATIVE VALUE OF VARIETIES FOR PRODUCTION OF OIL. The Analyses of Nine Varieties of Peanuts Grown in Different Parts of Alabama.

In Table V the analyses \* of one sample of each variety for different years are shown in columns 1 and 2. The chemical analyses are based on composite samples of shelled nuts of each variety, made up of nuts grown that year in several different localities.

TABLE V. *Percentage of Oil in Shelled Nuts and Pounds of Oil Per Ton of Unshelled Nuts for Different Varieties.*

| VARIETY         | Oil in Shelled Nuts |                  |                        | Average percent of sound peas in unshelled pods | Average percent of oil in unshelled pods | Average pounds of oil per ton of unshelled pods | Rank for making oil |
|-----------------|---------------------|------------------|------------------------|-------------------------------------------------|------------------------------------------|-------------------------------------------------|---------------------|
|                 | Cullman Co 1915     | All Samples 1916 | Average percent of oil |                                                 |                                          |                                                 |                     |
|                 |                     |                  |                        |                                                 |                                          |                                                 |                     |
|                 |                     |                  |                        |                                                 |                                          |                                                 |                     |
| All tests       | All tests           | All tests        |                        |                                                 |                                          |                                                 |                     |
| Virginia Runner | 43.68               | 48.93            | 46.30                  | 53.30                                           | 24.67                                    | 493                                             | 7                   |
| Tennessee Red   | 45.70               | 47.06            | 46.38                  | 56.90                                           | 26.39                                    | 527                                             | 5                   |
| N. C. Runner    | 40.86               | 50.13            | 45.49                  | 57.70                                           | 26.24                                    | 524                                             | 6                   |
| Virginia Bunch  | 45.27               | 47.00            | 46.13                  | 16.00                                           | 21.21                                    | 424                                             | 8                   |
| McGovern        |                     | 48.47            | 48.47                  | 56.60                                           | 27.43                                    | 548                                             | 4                   |
| Valencia        | 47.42               | 48.78            | 48.10                  | 59.50                                           | 28.61                                    | 572                                             | 3                   |
| Red Spanish     | 48.60               | 47.57            | 48.08                  | 72.10                                           | 34.66                                    | 693                                             | 2                   |
| White Spanish   | 48.52               | 45.03            | 46.77                  | 75.10                                           | 35.12                                    | 702                                             | 1                   |
| Jumbo           | 45.15               |                  | 45.15                  | 39.30                                           | 17.74                                    | 354                                             | 9                   |

The table shows that the percent of oil is higher in the 1916 samples than in the 1915 samples except for two varieties. The figures show a variation in the average oil content of the different varieties from 48.47 percent in the meats of the McGovern to 45.15 percent in the shelled peas of the Jumbo. The meats of the Red Spanish afforded 2.54 percent of oil more than those of the White Spanish; but the percentage of sound peas in the White Spanish was greater by 3 percent than in the Red Spanish. The amount of oil in a ton of White Spanish was largest, 702 pounds; next came Red Spanish, with 693 pounds.

The column containing the pounds of oil in one ton of unshelled nuts shows that some varieties are much more valuable for oil purposes than other varieties. A ton of Jumbo contained 354 pounds of oil, while a ton of White Spanish contained 702 pounds, a difference of 348 pounds in favor of this Spanish variety. The oil mills cannot afford to overlook this difference, nor can the growers who expect to sell the peanuts for oil production. A variety like North Carolina Runner, which some farmers think especially productive,

yields, under the conditions of these experiments, 273 pounds of oil less per ton of unhulled nuts than the average of the two Spanish varieties.

The oil in the peanut hulls is not included in the above table. U. S. Department of Agriculture Farmers' Bulletin No. 751, page 9, shows that the oil in the peanut hulls of different varieties varies from .73 percent in the Virginia Runner, to 3.53 percent in the Virginia Bunch. The analyses of hulls \* at Auburn shows 1.2 percent oil, 5.38 percent protein, 3.97 percent ash, 65.6 percent crude fiber, and 15.6 percent carbohydrates.

Based on the average percent of oil and of sound peas in the above table, the varieties of unshelled peanuts take the following rank in pounds of oil per ton:

|                             |     |
|-----------------------------|-----|
| White Spanish .....         | 702 |
| Red Spanish .....           | 693 |
| Valencia .....              | 572 |
| McGovern .....              | 548 |
| Tennessee Red .....         | 527 |
| North Carolina Runner ..... | 524 |
| Virginia Runner .....       | 493 |
| Jumbo .....                 | 354 |

#### OIL PRODUCTION AND YIELD AS REPORTED BY THE OIL MILLS.

From a questionnaire that was sent to a number of Alabama oil mills known to be crushing peanuts, the following facts were learned. These manufacturers are using the Anderson Expeller type of mill, which has a capacity ranging from 400 to 600 gallons of oil per day of 24 hours. The operators of these mills report that this machinery extracts from 92 to 95 percent of the oil contained in the peanuts.

They report from a ton of peanuts of the Spanish varieties, from 600 to 700 pounds of oil and from 1200 to 1300 pounds of peanut cake or meal. A ready sale for all peanut products is reported by the mills.

Some mills report that the color of the shelled peas is a matter of no importance. Others express a preference for "white" peanuts. All mills except the one at Brundidge prefer the White Spanish variety. The Brundidge mill prefers the North Carolina Runner, stating that its yield is higher than the yield of Spanish. The yield of peanuts in the locality of the mills in 1916 was estimated by the mills at 850 pounds of nuts per

\* Made in the Chemical Laboratory of the Alabama Experiment Station.



acre, and the average price for the past season was placed at about 3 cents per pound.

#### PREPARATION AND PLANTING.

Peanuts are grown on a wide range of soils, but those best adapted are sandy or loamy. Soils having considerable clay and lime produce good crops. A hard compact soil is poorly adapted because the pod stems called "needles" or "pegs" do not penetrate its surface, nor is poorly drained and sour land well suited. The mechanical condition of the soil is important. A liberal amount of humus, and lime and available plant food is essential to securing the largest yields.

Land intended for peanuts and not occupied by a winter crop should be plowed in the early spring. In case it is so occupied, the soil should be plowed as soon as the spring crop is removed. Where there is considerable trash on the surface from some preceding crop, this trash should be plowed under before planting in time for it to rot or at least to permit the soil to settle. About the same treatment given to land to prepare it for cotton is sufficient to prepare it for peanuts.

The importance of planting peanuts after a clean cultivated crop should not be overlooked. If the preceding crop had an abundance of grass and weeds it will be difficult to keep the peanut crop clean. It is not good practice to plant peanuts after peanuts. Some regular system of rotation of crops should be followed.

Planting a row of peanuts in the middles of corn rows, as practiced in southeast Alabama, has the advantage of making a peanut crop with little expense except the cost of the seed and the planting. The peanuts are cultivated at the same time the corn is cultivated. This is a satisfactory practice where the peanuts are gathered by hogs (except that it increases the amount of fencing); but when they are gathered for commercial purposes, the corn plants hinder the harvesting.

The peanuts are not planted on high beds because such beds dry out quickly, which condition tends to make a poor stand.

For the bunch variety, the rows may be made from  $2\frac{1}{2}$  to 3 feet wide, that is just wide enough to permit easy cultivation with ordinary cultivating implements. For the running variety, the rows should be from 3 to  $3\frac{1}{2}$  feet wide.



The seed of the bunch varieties may be dropped from 4 to 8 inches apart in the drill. The running type may be dropped from 12 to 15 inches apart in the drill. The seeding should be so thick that the vines will nearly cover the ground when they are fully grown. Planting should not begin until the middle of the usual period for planting cotton, and for the Spanish or early maturing varieties it may continue until the first of June, or even until the middle of June. The soil should be thoroughly warm.

#### AMOUNT OF SEED.

The following table shows the number of pounds of both shelled and unshelled peanuts of several of the leading varieties required to plant an acre at the various distances mentioned.

TABLE VI. *Pounds of Peanuts (from Table IV) Required to Plant an Acre at Stated Distances.*

| Variety       | Distance<br>Between Rows | Distance<br>Between Plants | Shelled<br>Peanuts | Unshelled<br>Peanuts |
|---------------|--------------------------|----------------------------|--------------------|----------------------|
|               | Feet                     | Inches                     | Lbs.               | Lbs.                 |
| White Spanish | 2½                       | 6                          | 31.5               | 41.9                 |
|               | 2½                       | 8                          | 23.6               | 31.4                 |
|               | 2½                       | 10                         | 18.9               | 25.1                 |
|               | 3                        | 6                          | 26.3               | 35.0                 |
|               | 3                        | 8                          | 19.6               | 26.3                 |
|               | 3                        | 10                         | 15.8               | 21.0                 |
| Red Spanish   | 2½                       | 6                          | 35.4               | 49.1                 |
|               | 2½                       | 8                          | 26.6               | 36.8                 |
|               | 2½                       | 10                         | 21.2               | 29.4                 |
|               | 3                        | 6                          | 29.5               | 40.9                 |
|               | 3                        | 8                          | 22.1               | 30.7                 |
|               | 3                        | 10                         | 17.7               | 24.5                 |
| N. C. Runner  | 3                        | 10                         | 18.5               | 32.1                 |
|               | 3                        | 12                         | 15.4               | 26.8                 |
|               | 3                        | 16                         | 11.5               | 20.1                 |
|               | 3½                       | 10                         | 15.9               | 27.6                 |
|               | 3½                       | 12                         | 13.3               | 23.0                 |
|               | 3½                       | 16                         | 9.9                | 17.3                 |

The above figures are based on the planting of only one shelled nut in a place or "hill," and on the assumption that all of the nuts are sound. Those who prefer to drop more than one seed in a hill should increase the figures accordingly.

From the above, and after allowing for faulty nuts and occasional placing of two nuts in a hill, we may conclude that about the following amounts of seed should be provided per acre:

|                                                                                     |        |
|-------------------------------------------------------------------------------------|--------|
| For Spanish varieties, rather close planting (6 x 30 in.)                           | 7 pks. |
| For Spanish varieties, thin planting (10 x 36 in.)                                  | 4 pks. |
| For North Carolina or similar running kinds, thick planting (10 x 36 in.)           | 7 pks. |
| For North Carolina or similar running varieties, rather thin planting (12 x 42 in.) | 5 pks. |

A special peanut planter, or an ordinary Cole planter and doubtless other types of one-horse planters may be used for planting shelled peanuts. The seed should be covered from  $1\frac{1}{4}$  to 2 inches deep.

The varieties of peanuts that have large pods should be shelled in order to secure a good stand. Such varieties as the White and Red Spanish may be planted without shelling the nuts. However, shelling of any variety insures more prompt germination and a better stand.

#### CULTIVATION.

It is well to harrow the rows to destroy the young weeds and grass before the peanuts come up. One cultivation or more with a weeder or light spike-tooth harrow should be given before the plants get much growth. Following this time, the ordinary implements used for the cultivation of cotton may be employed. The cultivation may continue close up to the plant, until the fruit stems begin to form, after which time the cultivating implements should not run close to the row. The covering of the blooms with dirt is unnecessary.

#### HARVESTING.

A farmer should judge when is the proper time to harvest the peanuts. The tops of the vines usually turn yellow and some of the leaves begin to drop off when the peanuts are ripe. If the harvesting is delayed the early maturing nuts of the Spanish varieties may sprout in the ground.

The harvesting may be done by hand or plow. Varieties whose pods cling well may be pulled up from very sandy land by hand. This is a slow method. An ordinary turning plow with its mold board removed to avoid covering the plants may be employed to raise the plants. The bunches may be collected in piles with an ordinary hay fork.

#### CURING AND PICKING.

The plants are usually left on the ground, after harvesting, for at least two or three hours. They should then be stacked. This is done by firmly setting up

stakes about 6 feet high, at the bottom of which are nailed two or three cross pieces 3 or 4 feet long. Around this stake the plants are stacked with the vines exposed, and the nuts inward. Ventilation is thus secured for the peanuts within, while they are protected from the weather by the vines.

From 15 to 20 such stacks will be necessary for one acre. The stacks should be capped with grass and remain 3 or 4 weeks in the field until the pods have become dry. They are then ready for a picker.

Some of the Florida growers have made use of a curing shed. On the posts are spiked cross timbers and on these timbers horizontal poles are placed sufficiently close to support the green peanut vines. From one floor of poles to the next is kept a vertical distance of about 5 or 6 feet. This space allows complete ventilation and the peanuts remain spread upon the poles until they become thoroughly dried. This method of curing secures a better quality of hay and bright pods.

The picking of the peanuts off the stems by hand is slow and expensive. In a community where a large acreage is planted a custom picker may be operated profitably. There are several types which are now offered on the market. One type depends for the removing of the nuts from the vines on the use of a system of vibrating wire screens, and is used exclusively for peanut *picking*. The other type of picker is an ordinary grain *thresher* with a special cylinder and concave for peanuts. This last machine readily removes the nuts and makes them ready for oil mill purposes, but according to the statement of the president of one of the peanut oil mills in Alabama, the peanut *thresher* breaks up the pods and injures the nuts for planting purposes.

#### PEANUT HAY AND STRAW.

Peanut vines make a fine quality of hay if cut before the leaves drop. Their chemical composition is nearly that of alfalfa hay. Valencia, Virginia Bunch, and the Spanish varieties are the best suited for hay making on account of their upright habit of growth, which makes them easy to mow.

Peanut straw (the cured peanut plant after the filled pods have been picked off) has a larger proportion of woody stems and a smaller proportion of leaves than peanut hay, which render the former somewhat less nutritious than peanut hay.

TABLE VII. *Yields and Percentages of Dried Peanut Straw (Vines After Removal of Nuts.)*

| VARIETY             | D. B. Lewis,<br>Jasper, 1914 | D. B. Lewis,<br>Jasper, 1915 | D. B. Lewis,<br>Jasper, 1916 | Experiment Station,<br>Auburn, 1916 | Average | Average percent<br>of stover | Average percent of<br>dried pods |
|---------------------|------------------------------|------------------------------|------------------------------|-------------------------------------|---------|------------------------------|----------------------------------|
|                     | Lbs.                         | Lbs.                         | Lbs.                         | Lbs.                                | Lbs.    | Lbs.                         | Lbs.                             |
| Valencia -----      | 900                          | 3600                         | 952                          | 3210                                | 2165    | 63                           | 37                               |
| Red Spanish -----   | 1332                         | 2250                         | 1558                         | 2309                                | 1862    | 61                           | 39                               |
| White Spanish ----- | 2005                         | 2750                         | 1434                         | 1303                                | 1873    | 62                           | 38                               |
| Tennessee Red ----  | 2431                         | 3000                         | 877                          | 2109                                | 2104    | 62                           | 38                               |
| Virginia Bunch ---- | 1253                         | 2200                         | 1482                         |                                     | 1234    | 62                           | 38                               |
| Virginia Runner --  |                              | 3000                         | 1620                         | 2717                                | 1834    | 67                           | 33                               |
| North Carolina ---- | 1610                         | 3350                         | 1914                         | 2392                                | 2316    | 68                           | 32                               |

Peanut straw as a rule is not as bright as peanut hay. The plants are exposed to sunshine and dews during the curing. Table VII shows that the average yield of peanut straw per acre ranges from 1234 pounds to 2316 pounds per acre. The running varieties yield a higher percentage of straw than the bunch type. On ordinary soil, from three-fourths to one ton of straw per acre is considered a fair yield.

#### CHEMICAL COMPOSITION OF PEANUT STRAW.

The chemical composition of peanut straw, as reported by the Chemical Department of this Station, is as follows:

Water, 10.72 percent; ash, 6.03 percent; crude protein, 10.69 percent; crude fat, 1.66 percent; crude fiber, 29.5 percent; carbohydrates, 41.39 percent.

Its composition shows that it carries 1.2 percent potash, and 0.50 percent phosphoric acid.

#### RESIDUAL FERTILIZING EFFECT OF PEANUTS.

This table records the result of a test made to show the fertilizing effect of peanuts on following crops. As indicated in the table, peanuts were harvested in different ways, and the succeeding yields of rye and sorghum hay are compared with the hay yields from a plot on which corn had been grown.



TABLE VIII. *Residual Fertilizing Effect of Peanuts Compared With Corn.* (\*)

| Crop—Summer of 1899            | Succeeding Crops              |                              |
|--------------------------------|-------------------------------|------------------------------|
|                                | Rye<br>Winter of<br>1899-1900 | Sorghum<br>Summer of<br>1900 |
|                                | Lbs. per Acre                 | Lbs. Per Acre                |
| Spanish peanuts—nuts harvested | 1080                          | 4480                         |
| Spanish peanuts—grazed by hogs | 4280                          | 4000                         |
| Running peanuts—turned under   | 2582                          | 6320                         |
| Corn—ears pulled               | 1080                          | 5040                         |

The peanut plots gave a yield of rye higher than that of the non-legume plot in two instances; where the peanuts were grazed and the plot got the benefit of the droppings from animals, and where the luxuriant growth of vines were turned under on account of the running peanuts failing to make.

Two of the peanut plots yielded less sorghum hay than did the corn plot, and only on the plot on which the vines were turned under did the yield of this second succeeding crop prove greater than that following corn.

The conclusion is that a crop of peanuts harvested in the usual way for seed does not improve the soil for a succeeding crop.

#### INOCULATION OF PEANUTS.

The peanut is a legume, roots of which should be abundantly supplied with tubercles to make sure that it makes use of the nitrogen of the air rather than that of the soil. So far as the observations of the writers go, the peanut plant on Southern soils is naturally stocked with tubercles. Hence artificial inoculation, either with soil or with pure cultures, seems to be a useless expense.

Probably the usual occurrence of tubercles on the roots of the peanut plant results from natural inoculation carried on the seed in the dust from the old field. This dust from the hulls comes in contact with the shelled nuts in any process of shelling, and is of course still more abundant if unshelled nuts are planted.

Experiments made on sandy land on the farm of the Alabama Experiment Station, at Auburn, showed no increase in yield from inoculating peanuts with appropriate soil, and no apparent increase in the number of tubercles per plant.

(\*) Bul. 104, Alabama Experiment Station.



## DISEASES OF PEANUTS.

*Leaf spot*, which appears as a small, brown spot on the leaves and stems (See spots on leaves of White Spanish variety, Pl. I, Fig. 2), is caused by a fungus disease (*Cercospora personata*). It usually attacks the grown leaves, though it may attack the young ones, causing them to fall off, thereby reducing the value of the hay and the yield of peanuts.

This leaf spot fungus may be carried from one year to the next on old peanut leaves and stems. Crop rotation and plowing under all old vines and stems are, therefore, recommended as good farm practice to lessen the amount of the disease in a succeeding peanut crop.

*Sclerotial rot*, (caused by *Sclerotium Rolfsii*) attacks the roots and peas, and destroys the pods. The top of the plant may be healthy in appearance, but when it is pulled up, many of its pods may be found completely rotten. The rotten pods may appear wet or dry, as other organisms of decay may have become associated with the decayed nuts.

No means of combatting sclerotial rot is known.

*Red rot* attacks the pods of the peanut and causes them to appear brown or reddish. The crop should be dug as soon as it matures to avoid loss from this disease. (See Alabama Station Bulletin No. 180).

## AVERAGE YIELD OF PEANUTS.

According to figures furnished by the Bureau of Crop Estimates of the United States Department of Agriculture, the average yield of peanuts for the United States for the past five years has been 38.6 bushels per acre. For the same period, the Southern States averaged as follows:

| State                | Bushels | State             | Bushels |
|----------------------|---------|-------------------|---------|
| North Carolina ..... | 42      | Alabama .....     | 37      |
| South Carolina ..... | 45      | Louisiana .....   | 32      |
| Georgia .....        | 40      | Mississippi ..... | 34      |
| Florida .....        | 36      | Texas .....       | 33      |
| Tennessee .....      | 48      | Oklahoma .....    | 38      |

As a rule, the yield is very nearly in proportion to the thickness of the stand. Especially is this true with the Spanish varieties. The largest yield on record is one made on the farm of Dr. J. F. Yarbrough, at Columbia, Alabama. The yield, as reported by Dr. Yarbrough, on the basis of 24 pounds of Spanish peanuts.

per bushel, was  $214\frac{1}{2}$  bushels on an acre. On the basis of 28 pounds per bushel the yield was 183.9 bushels. These peanuts were planted in rows 17 inches apart. The nuts were very carefully placed 4 inches apart in the drill. Cultivation was chiefly with a weeder and by hand. The soil was a deep, loose sand, fertilized per acre as follows:

1,000 pounds ground limestone.  
1,600 pounds 16 percent acid phosphate.  
1,600 pounds kainit.

### FERTILIZER EXPERIMENTS WITH PEANUTS.

The experiments reported in these pages were made by selected farmers in several counties. The land was selected and plots measured by a representative of the Experiment Station, who was also present at the harvesting of as many of the experiments as practicable. The fertilizer for each plot was separately weighed out, sacked and fully labeled at Auburn.

In interpreting these experiments the reader should bear in mind that it is more difficult to make accurate experiments with peanuts than with cotton or corn, since poor stands of peanuts are common.

Hence some of the experiments made are only briefly tabulated as inconclusive or not published at all.

The rule has been to wait one to two weeks after the nuts are dug before taking the weight of dry peanuts, on which the tables in this bulletin are based. The unshelled nuts were valued at 4 cents per pound and fertilizers at prices prevailing just before the European War.

HOUSTON COUNTY, 2 MILES SOUTH OF DOTHAN.

S. A. MULLINS, 1911.

*Gray sandy loam, with stiffer yellow subsoil.*

The land on which this experiment was made had been in cultivation many years. No leguminous crop had grown on it during the last three years.

A mixture of acid phosphate and kainit (Plot 8) was the only one showing any profit. The addition of cottonseed meal to acid phosphate and kainit did not increase the yield.

*Experiment in Houston County, 1911*  
*Dothan*

| Plot No. | Amount fertilizer<br>per acre | KIND OF FERTILIZER  | Yield of peanuts<br>per acre | Increase over un-<br>fertilized plot | Profit from fertilizer<br>usual price |
|----------|-------------------------------|---------------------|------------------------------|--------------------------------------|---------------------------------------|
|          | Lbs.                          |                     | Lbs.                         | Lbs.                                 |                                       |
| 1        | 200                           | C. S. Meal.....     | 704                          | -128                                 | -\$8 12                               |
| 2        | 200                           | Kainit.....         | 864                          | 32                                   | -0.40                                 |
| 3        |                               | No fertilizer.....  | 832                          | ---                                  | ---                                   |
| 4        | 240                           | Acid phosphate..... | 768                          | -56                                  | -3.64                                 |
| 5 {      | 200                           | C. S. Meal.....     | 864                          | 48                                   | -2.76                                 |
|          | 240                           | Acid phosphate..... |                              |                                      |                                       |
| 6 {      | 200                           | C. S. Meal.....     | 832                          | 24                                   | -3.44                                 |
|          | 200                           | Kainit.....         |                              |                                      |                                       |
| 7        |                               | No fertilizer.....  | 800                          | ---                                  | ---                                   |
| 8 {      | 240                           | Acid phosphate..... | 896                          | 96                                   | 0.76                                  |
|          | 200                           | Kainit.....         |                              |                                      |                                       |
| 9 {      | 200                           | C. S. Meal.....     | 896                          | 96                                   | -2.24                                 |
|          | 240                           | Acid phosphate..... |                              |                                      |                                       |
|          | 200                           | Kainit.....         |                              |                                      |                                       |

COVINGTON COUNTY, 1 MILE SOUTHEAST OF OPP.

BEN J. BARNES, 1913.

*Gray sandy loam, with stiffer yellow subsoil.*

This experiment was made on poor, gray sandy upland which had been cleared of its long leaf pine for eight years. The same plots were also used for fertilizer experiments with peanuts at Opp in 1914.

Similar soil on the same farm but on different plots was employed for this test in 1915.

In 1913 the largest net profit, \$28.32, above the cost of fertilizer, was afforded by Plot 4, fertilized as follows:

240 pounds acid phosphate per acre.

200 pounds kainit per acre.

600 pounds slacked lime per acre.

Most of this profit was due to lime, the separate effect of 600 pounds of which was to increase the yield of dry nuts by 538 pounds per acre. This is a net profit of \$18.52 per acre, after deducting the cost of 600 pounds of slacked lime at \$10.00 per ton.

*Experiments in Covington County.*

| Plot No. | Amount of fertilizer per acre | KIND OF FERTILIZER | Opp, 1913                 |                                 |                        | Opp, 1914                 |                                 |                        | Opp, 1915                 |                                 |                        |
|----------|-------------------------------|--------------------|---------------------------|---------------------------------|------------------------|---------------------------|---------------------------------|------------------------|---------------------------|---------------------------------|------------------------|
|          |                               |                    | Yield of peanuts per acre | Increase over unfertilized plot | Profit from fertilizer | Yield of peanuts per acre | Increase over unfertilized plot | Profit from fertilizer | Yield of peanuts per acre | Increase over unfertilized plot | Profit from fertilizer |
| 1        | Lbs. 240                      | Acid phosphate---- | Lbs. 1075                 | Lbs. 322                        | \$11.20                | Lbs. 903                  | Lbs. 279                        | \$ 9.48                | Lbs. 640                  | Lbs. 304                        | \$10.48                |
| 2        | 200                           | Kainit-----        | 860                       | 107                             | 2 88                   | 774                       | 150                             | 4.60                   | 512                       | 176                             | 4.78                   |
| 3        | 000                           | No fertilizer----- | 753                       | -----                           | -----                  | 624                       | -----                           | -----                  | 336                       | -----                           | -----                  |
| 4        | 240                           | Acid phosphate---- | 1613                      | 860                             | 28.32                  | 1246                      | 627                             | 19.00                  | 896                       | 560                             | 15.46                  |
|          | 200                           | Kainit-----        |                           |                                 |                        |                           |                                 |                        |                           |                                 |                        |
|          | 600                           | Lime (slaked)----- |                           |                                 |                        |                           |                                 |                        |                           |                                 |                        |
| 5        | 240                           | Acid phosphate---- | 1075                      | 322                             | 9.80                   | 1032                      | 419                             | 13.68                  | 624                       | 288                             | 7.58                   |
|          | 200                           | Kainit-----        |                           |                                 |                        |                           |                                 |                        |                           |                                 |                        |
|          | 200                           | C. S. Meal-----    |                           |                                 |                        |                           |                                 |                        |                           |                                 |                        |
| 6        | 240                           | Acid phosphate---- | 1290                      | 537                             | 15.40                  | 1011                      | 403                             | 10.04                  | 704                       | 368                             | 7.78                   |
|          | 200                           | Kainit-----        |                           |                                 |                        |                           |                                 |                        |                           |                                 |                        |
|          | 000                           | No fertilizer----- |                           |                                 |                        |                           |                                 |                        |                           |                                 |                        |
| 7        | 240                           | Acid phosphate---- | 753                       | -----                           | -----                  | 602                       | -----                           | -----                  | 336                       | -----                           | -----                  |
| 8        | 240                           | Acid phosphate---- | 1183                      | 430                             | 14.82                  | -----                     | -----                           | -----                  | 800                       | 464                             | 15.75                  |
|          | 100                           | Kainit-----        |                           |                                 |                        |                           |                                 |                        |                           |                                 |                        |

Next to lime, acid phosphate was the most important fertilizer for peanuts on this soil in 1913; even when used alone at the rate of 240 pounds per acre it increased the yield by 322 pounds of dry peanuts, affording a profit of \$11.20 per acre. The average increase due to 240 pounds acid phosphate per acre was 269 pounds of dry nuts per acre.

Potash was also helpful, but to a less degree. The average increase due to 200 pounds of kainit per acre was 54 pounds of dry nuts per acre.

#### 1914.

The largest net profit, \$19.00 per acre, was again on the plot fertilized with slacked lime, acid phosphate and kainit. In this year lime was responsible for an increase of 208 pounds of dry nuts, which at 4 cents per pound, is a profit of \$5.32 per acre, for the lime alone, in addition to a profit of \$13.68 per acre due to the mixture of acid phosphate and kainit.

Again acid phosphate was, next to lime, the most important fertilizer. This fertilizer used *alone* increas-



ed the yield of nuts by 279 pounds per acre, and its *average* increase was 274 pounds of dry nuts per acre.

The average increase resulting from the use of 200 pounds of kainit per acre was 145 pounds of dry nuts per acre.

1915.

In 1915 the largest increase, 560 pounds of dry nuts, was again made by Plot 4, fertilized with acid phosphate, kainit and slacked lime. The profit on this plot this year was \$15.46 per acre. Lime was separately responsible for 272 pounds of dry nuts per acre, or a profit of \$7.88.

This year acid phosphate afforded an *average* increase of 208 pounds of dry nuts per acre. The use of 200 pounds of kainit afforded an average increase of 80 pounds of dry nuts.

Thus the results of each of the three years agree in showing that the most profitable investment was that in lime; the next most profitable was the investment in acid phosphate; while the 200 pounds of kainit increased the yield to a less extent, but to a point that was profitable on the basis of prices for potash prevailing before the European war.

However, we should not expect such favorable results from lime, except when applied, as in all these experiments, in combination with the other fertilizers, notably acid phosphate.

*Separate Effect of Cotton Seed Meal, Acid Phosphate, Kainit and Slaked Lime in Increasing the Yield of Dry Nuts Per Acre at Opp, Covington County.*

|                                                                     | 1913 | 1914 | 1915 |
|---------------------------------------------------------------------|------|------|------|
|                                                                     | lbs. | lbs. | lbs. |
| Increase of dry nuts per acre when cotton seed meal was added ..... |      |      |      |
| To acid phosphate and kainit plot .....                             | 215  | —16  | 80   |
| Increase of dry nuts per acre when acid phosphate was added:        |      |      |      |
| To unfertilized plot .....                                          | 322  | 279  | 304  |
| To kainit plot .....                                                | 215  | 269  | 112  |
| <i>Average increase with acid phosphate</i> .....                   | 269  | 274  | 208  |
| Increase of dry nuts per acre when kainit was added:                |      |      |      |
| To unfertilized plot .....                                          | 107  | 150  | 176  |
| To acid phosphate plot .....                                        | 0    | 140  | —16  |
| <i>Average increase with kainit</i> .....                           | 54   | 145  | 80   |
| Increase of dry nuts per acre when slacked lime was added:          |      |      |      |
| To acid phosphate and kainit plot .....                             | 538  | 208  | 272  |



LEE COUNTY, 1 MILE SOUTHEAST OF AUBURN.  
W. M. DEAN, 1915.

*Gray sandy loam, with stiffer yellow subsoil.*

This sandy upland had been cleared for several years.

The largest increase in yield, 336 pounds of dry nuts per acre, was obtained on Plot 4, fertilized with acid phosphate, kainit and lime. This was closely followed by Plot 8, fertilized with 240 pounds of acid phosphate and 100 pounds of kainit, which afforded an increase of 320 pounds of dry nuts, and a profit of \$9.99 per acre. The separate increase due to lime is calculated as 208 pounds of dry nuts, or a profit of \$5.37 per acre.

Acid phosphate was the most important single fertilizer constituent, its average increase being 216 pounds of dry nuts per acre.

Kainit in each of three combinations failed to effect any material increase in yield, and on every plot was unprofitable, whether used at the rate of 200 or 100 pounds per acre.

*Experiments in Lee and Cullman Counties.*

| Plot No. | Amount of fertilizer per acre | KIND OF FERTILIZER   | Auburn, 1915              |                                 |                        | Cullman, 1915             |                            |                        |
|----------|-------------------------------|----------------------|---------------------------|---------------------------------|------------------------|---------------------------|----------------------------|------------------------|
|          |                               |                      | Yield of peanuts per acre | Increase over unfertilized plot | Profit from fertilizer | Yield of Peanuts per acre | Increase over unfertilized | Profit from fertilizer |
| 1        | 200                           | Acid phosphate----   | Lbs. 688                  | Lbs. 304                        | \$10.48                | 1925                      | Lbs. -220                  | \$-10.48               |
| 2        | 200                           | Kainit-----          | 384                       | 000                             | -2 26                  | 1888                      | -257                       | -12.54                 |
| 3        | 000                           | No fertilizer----    | 384                       | ----                            | -----                  | 2145                      | -----                      | -----                  |
| 4        | { 240                         | Acid phosphate.. }   | 720                       | 336                             | 6.50                   | 1906                      | -179                       | -14.10                 |
|          | { 200                         | Kainit----- }        |                           |                                 |                        |                           |                            |                        |
|          | { 600                         | Lime (slaked)----- } |                           |                                 |                        |                           |                            |                        |
| 5        | { 240                         | Acid phosphate.. }   | 512                       | 128                             | 1.18                   | 1650                      | -376                       | -18.98                 |
|          | { 200                         | Kainit----- }        |                           |                                 |                        |                           |                            |                        |
|          | { 200                         | C. S. Meal----- }    |                           |                                 |                        |                           |                            |                        |
| 6        | { 240                         | Acid phosphate.. }   | 672                       | 288                             | 4.58                   | 1283                      | -683                       | -34.26                 |
|          | { 200                         | Kainit----- }        |                           |                                 |                        |                           |                            |                        |
|          | { 200                         | Kainit----- }        |                           |                                 |                        |                           |                            |                        |
| 7        | 000                           | No fertilizer----    | 384                       | ----                            | -----                  | 1906                      | -----                      | -----                  |
| 8        | { 240                         | Acid phosphate.. }   | 704                       | 320                             | 9.99                   | 1246                      | -666                       | -29.21                 |
|          | { 100                         | Kainit----- }        |                           |                                 |                        |                           |                            |                        |

CULLMAN COUNTY, 1½ MILES NORTH OF CULLMAN.

I. O. O. F. HOME, ED. B. MILLER, SUPT., 1915.

*Yellowish gray fine sandy soil, with stiffer yellow subsoil.*

This upland soil had been in cultivation only six years, and, judging by the yield, apparently it was in a better state of fertility than other soils used in peanut fertilizer tests.

On such land, and with a rainy season after the middle of July, 1915, all fertilizers were without favorable effect. Indeed they seemed to decrease the yield under these conditions.

*Separate Effect of Cotton Seed Meal, Acid Phosphate, Kainit and Slaked Lime in Increasing the Yield of Dry Nuts Per Acre at Auburn and Cullman.*

|                                                                | Auburn<br>1915 | Cullman<br>1915 |
|----------------------------------------------------------------|----------------|-----------------|
| Increase of dry nuts per acre when cotton seed meal was added: | Lbs.           | Lbs.            |
| To acid phosphate and kainit plot----                          | 160            | —307            |
| Increase of dry nuts per acre when acid phosphate was added:   |                |                 |
| To unfertilized plot -----                                     | 304            | —220            |
| To kainit plot -----                                           | 128            | —119            |
| Average increase with acid phosphate                           | 216            | —170            |
| Increase of dry nuts per acre when kainit was added:           |                |                 |
| To unfertilized plot -----                                     | 0              | —257            |
| To acid phosphate plot -----                                   | —176           | —156            |
| Average increase with kainit -----                             | —88            | —207            |
| Increase of dry nuts per acre when slaked lime was added:      |                |                 |
| To acid phosphate and kainit plot ----                         | 208            | 197             |

GENERAL SUGGESTIONS FOR FERTILIZING PEANUTS.

1. Acid phosphate (or other source of available phosphoric acid, as Basic Slag) seems advisable for peanuts grown on practically all sandy and other soils that are especially well adapted to peanuts.

2. The amount of acid phosphate should probably range between 200 and 300 pounds per acre.

3. While potash is shown by some of these experiments to be helpful to peanuts grown on certain poor sandy soils, it is of less importance than available phosphoric acid. Present high prices and scarcity make the use of potash at this time impracticable and unprofitable for peanuts. When prices decline sufficient-

ly, 100 pounds of kainit per acre would seem, from certain of these experiments, to offer more promise of profit than 200 pounds per acre.

4. While in some of these experiments cottonseed meal seems to have increased the yield of peanuts on very poor soil, yet, until such evidence is stronger, the writers would not advise any investment in any form of nitrogen as a fertilizer for peanuts.

5. Some form of lime is generally helpful to peanuts, and on acid soils is strongly needed. Slaked lime at the rate of 600 pounds per acre gave profitable results in most of these experiments. It is believed that the use of about 1,000 pounds or more of ground limestone would be the most satisfactory and economical form in which to apply lime.

6. No form of lime should come in immediate contact with acid phosphate. The phosphate may be drilled in at or before planting. The lime may be applied in any convenient way, preferably before planting, and well harrowed in or otherwise mixed with the surface soil.

## APPENDIX.

## INCONCLUSIVE EXPERIMENTS.

In Butler County, 8 miles north of Greenville, an experiment conducted by E. A. Simmons in 1916 proved inconclusive, because of a lack of uniformity in the stand due to damage by moles. (See page 32).

An experiment conducted in 1916 in Cullman County, on the farm of the I. O. O. F. Home, proved inconclusive because of poor stand and lack of uniformity of the land.

Eighteen other experiments were begun in the counties named below, but for various reasons they were not carried to a conclusion, or else for various reasons the results are not available for publication.

| <i>County</i> | <i>Postoffice</i> | <i>Year</i> |
|---------------|-------------------|-------------|
| Barbour       | Clayton           | 1912        |
| Bullock       | Fitzpatrick       | 1915        |
| Butler        | Greenville        | 1912        |
| Butler        | Greenville        | 1913        |
| Butler        | Greenville        | 1914        |
| Butler        | Greenville        | 1915        |
| Coffee        | Enterprise        | 1914        |
| Coffee        | Enterprise        | 1915        |
| Covington     | Opp               | 1912        |
| Dale          | Pinckard          | 1911        |
| Elmore        | Tallassee         | 1912        |
| Escambia      | Atmore            | 1915        |
| Houston       | Dothan            | 1912        |
| Houston       | Dothan            | 1913        |
| Lee           | Auburn            | 1916        |
| Monroe        | Monroeville       | 1912        |
| Mobile        | Irvington         | 1914        |
| Pike          | Banks             | 1916        |

*Separate Effect of Cotton Seed Meal, Acid Phosphate and Kainit in Increasing the Yield of Nuts Per Acre at Dothan, Houston County, 1911.*

Increase of dry nuts per acre when cotton seed meal was added:

|                                               |           |
|-----------------------------------------------|-----------|
| To unfertilized plot                          | —128 lbs. |
| To acid phosphate plot                        | 104 lbs.  |
| To kainit plot                                | —8 lbs.   |
| To acid phosphate and kainit plot             | 0 lbs.    |
| <i>Average increase with cotton seed meal</i> | —8 lbs.   |

Increase of dry nuts per acre when acid phosphate was added:

|                                             |          |
|---------------------------------------------|----------|
| To unfertilized plot                        | —56 lbs. |
| To cotton seed meal plot                    | 176 lbs. |
| To kainit plot                              | 64 lbs.  |
| To cotton seed meal and kainit plot         | 72 lbs.  |
| <i>Average increase with acid phosphate</i> | 64 lbs.  |

Increase of dry nuts per acre when kainit was added:

|                                                |          |
|------------------------------------------------|----------|
| To unfertilized plot .....                     | 32 lbs.  |
| To cotton seed meal plot .....                 | 152 lbs. |
| To acid phosphate plot .....                   | 152 lbs. |
| To cotton seed meal and acid phosphate plot .. | 48 lbs.  |
| Average increase with kainit .....             | 96 lbs.  |

*Inconclusive Experiments in Butler and Cullman Counties, 1916.*

| Plot No. | Amount of fertilizer per acre | KIND OF FERTILIZER     | Greenville, 1916          |                                 | Cullman, 1916             |                                 |
|----------|-------------------------------|------------------------|---------------------------|---------------------------------|---------------------------|---------------------------------|
|          |                               |                        | Yield of peanuts per acre | Increase over unfertilized plot | Yield of peanuts per acre | Increase over unfertilized plot |
| 1        | 4000                          | Ground Limestone ..... | Lbs. 612                  | Lbs. -168                       | Lbs. 1040                 | Lbs. 192                        |
| 2        | 000                           | No fertilizer .....    | 780                       | ---                             | 848                       | ---                             |
| 3        | 240                           | Acid phosphate .....   | 1044                      | 322                             | 944                       | 166                             |
| 4        | 200                           | Kainit .....           | 876                       | 211                             | 896                       | 189                             |
| 5        | 200                           | C. S. Meal .....       | 768                       | 161                             | 672                       | 35                              |
|          | 240                           | Acid phosphate .....   |                           |                                 |                           |                                 |
| 6        | 200                           | C. S. Meal .....       | 1092                      | 542                             | 928                       | 362                             |
|          | 200                           | Kainit .....           |                           |                                 |                           |                                 |
| 7        | 000                           | No fertilizer .....    | 492                       | ---                             | 496                       | ---                             |
| 8        | 240                           | Acid phosphate .....   | 444                       | -29                             | 736                       | 224                             |
|          | 200                           | Kainit .....           |                           |                                 |                           |                                 |
| 9        | 200                           | C. S. Meal .....       | 612                       | 158                             | 576                       | 48                              |
|          | 240                           | Acid phosphate .....   |                           |                                 |                           |                                 |
| 10       | 200                           | Kainit .....           | 708                       | 274                             | 592                       | 48                              |
|          | 240                           | Acid phosphate .....   |                           |                                 |                           |                                 |
| 11       | 4000                          | Ground Limestone ..... | 660                       | 245                             | 544                       | -16                             |
|          | 240                           | Acid phosphate .....   |                           |                                 |                           |                                 |
| 12       | 200                           | Kainit .....           | 396                       | ---                             | 576                       | ---                             |
|          | 4000                          | Ground Limestone ..... |                           |                                 |                           |                                 |
|          | 000                           | No fertilizer .....    |                           |                                 |                           |                                 |



**ALABAMA**

**Agricultural Experiment Station**

OF THE

**Alabama Polytechnic Institute**

**AUBURN**

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**Growing Peanuts in Alabama**

A POPULAR EDITION OF BULLETIN NO. 193

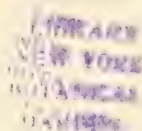
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By

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# GROWING PEANUTS IN ALABAMA

By

J. F. DUGGAR,  
E. F. CAUTHEN,  
J. T. WILLIAMSON,  
O. H. SELLERS.

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## SUMMARY.

The average yield of unshelled peanuts obtained from regular variety tests, made in different parts of the State and covering a period of five years, ranged from 871 pounds of McGovern to 1244 pounds of Red Spanish per acre. Taking the yield of Red Spanish as a basis (100 percent), the percentage yield of the different varieties averaged as follows:

|                     |     |                           |    |
|---------------------|-----|---------------------------|----|
| Red Spanish .....   | 100 | Tennessee Red .....       | 86 |
| Valencia .....      | 91  | Virginia Bunch .....      | 86 |
| White Spanish ..... | 88  | Virginia Runner .....     | 85 |
| McGovern .....      | 87  | North Carolina Runner ... | 84 |

The average percentage of shelled nuts or "meats" of each variety, obtained by carefully weighing and hand-shelling a given amount of dry unshelled peanuts, shows a remarkably wide variation, from 39.3 percent in Jumbo to 75.1 percent in White Spanish. The true commercial value of the crop of an acre is based, not on the number of pounds of unhulled peanuts, but on the number of pounds of "meats" produced.

The common varieties of peanuts are divided into two great classes—those having an upright or bunch habit of growth, and those having a low spreading or running habit. To the bunch varieties belong the White Spanish, Red Spanish, Valencia, Virginia Bunch, and Tennessee Red. Among the running varieties are the North Carolina or African, Virginia Runner, McGovern, and the Running Jumbo.

In a number of experiments there were found great differences in the weight of single unshelled peanuts, of "peas" of different varieties, and the average percentage of sound "peas" per pod. The heaviest unshelled peanuts were the Tennessee Red (246 pods to the pound), and the lightest, the White Spanish (461 pods to the pound).

Based on the average percentage of sound nuts of each variety and of its oil content, the varieties arranged according to the number of pounds of oil produced per ton take the following rank: White Spanish 702 pounds, Red Spanish 693 pounds, Valencia 572 pounds, McGovern 548 pounds, Tennessee Red 527 pounds, North Carolina Runner 524 pounds, Virginia Runner 493 pounds, and Jumbo 354 pounds.

The average yield of unshelled peanuts as reported by Alabama oil mills, is estimated at 850 pounds per acre. From a ton of Spanish peanuts the mills obtain from 600 to 700 pounds of oil, and from 1200 to 1300 pounds of peanut cake. All the oil mills reporting preferred the White Spanish variety, except one mill which preferred the North Carolina Runner because it claimed that the yield of the latter per acre is in excess of the other varieties.

From many complete fertilizer tests with peanuts, located in different parts of the State and covering a period of six years, it is concluded:

1. That acid phosphate at the rate of 200 to 300 pounds per acre produced a profitable increase in peanuts grown on sandy and other soils that are well adapted to this crop;

2. That potash applied in the form of kainit at the rate of 100 and 200 pounds per acre did not always prove profitable, except in a few experiments located on infertile sandy soil;

3. That slaked lime at the rate of 600 pounds per acre made a profitable increase in yield when applied on sandy soil;

4. That cottonseed meal as a source of nitrogen did not give profitable increases in yield, and is, therefore, not to be generally recommended for this leguminous crop.

The average yield of peanut straw (vines after removal of peanuts) from four experiments varied from 2316 pounds of North Carolina Runner, to 1234 pounds of Virginia Bunch per acre. The average percent of dried unhulled peanuts to the weight of the whole plant ranged from 32 percent in North Carolina Runner, to 39 percent in Red Spanish.

## INTRODUCTION.

The peanut industry is growing rapidly in Alabama. This rapid growth is coming as a result of the crop diversification campaigns, the change from the one crop system of cotton due to the invasion of the Mexican cotton boll weevil, and the growing demand for peanut oil and cake for stock feed and fertilizer.

In soil and climate Alabama is well adapted to peanuts. Its cottonseed oil mills are being converted into peanut mills to manufacture oil and cake. The farmer has most of the implements on hand needed for the planting and culture of this crop. The additional equipment most needed is a custom picker for each community that grows any considerable amount of peanuts.

## VARIETY TESTS OF PEANUTS.

Some of the experiments, from which the conclusions contained in this bulletin were drawn, were made on the Experiment Farm at Auburn. Most of them were made on farms scattered throughout the State. These latter tests constituted part of the work conducted under the provisions of the Local Experiment Law. Each experiment made away from Auburn was planned and supervised by a Station representative. The soil, fertilizer and cultural treatment for each variety in any particular experiment was the same. The same strains of seed peanuts were supplied to every experimenter making variety experiments in a given year. The experimenter or a representative of the Station harvested plots of uniform size and reported the weight of the nuts after they had been thoroughly dried.

In all cases, the experiments were located on some type of sandy soil, ranging from sandy loam, with clay subsoil, to fine sand. A complete commercial fertilizer was used under nearly all the experiments.

Bulletin No. 193 contains full explanations of the experiments. It contains tables of results which are omitted in this condensed bulletin.

## RELATIVE YIELDS OF VARIETIES.

For comparison, the yield of *unhulled nuts* of Red Spanish is taken as a basis, and hence this yield is rated at 100 percent. Then each variety is compared with the Red Spanish, but only in those years in which



the compared variety and the Red Spanish were both tested along side. The results are given below:

In 7 out of 12 experiments Red Spanish proved superior in yield to White Spanish.

|                     | <i>Pounds<br/>per Acre</i> | <i>Relative<br/>Yield</i> |
|---------------------|----------------------------|---------------------------|
| White Spanish ..... | 1094                       | 88                        |
| Red Spanish .....   | 1244                       | 100                       |

In 7 out of 12 tests Valencia was exceeded by Red Spanish:

|                   |      |     |
|-------------------|------|-----|
| Valencia .....    | 1137 | 91  |
| Red Spanish ..... | 1244 | 100 |

In 8 out of 10 experiments North Carolina Running was equalled, or exceeded in yield of unhulled nuts by Red Spanish:

|                             |      |     |
|-----------------------------|------|-----|
| North Carolina Runner ..... | 1068 | 84  |
| Red Spanish .....           | 1268 | 100 |

In 6 out of 10 tests Virginia Runner was surpassed in yield of unhulled nuts by Red Spanish:

|                       |      |     |
|-----------------------|------|-----|
| Virginia Runner ..... | 1087 | 85  |
| Red Spanish .....     | 1275 | 100 |

The comparison is still more unfavorable to Virginia Runner on the basis of pounds of meats per acre, since in a number of the tests this variety had a large proportion of pops. The four localities in which Virginia Runner exceeded Red Spanish in yield of unhulled nuts were Pinckard, Dale County; Honoraville, Butler County; Jasper, Walker County; and Auburn, Lee County. In only one of the six tests (Pinckard) did Virginia Runner afford a larger weight of *meats* per acre.

In 3 out of 5 tests McGovern was exceeded in yield of unhulled nuts by Red Spanish, and in every year in which the meats were separated Red Spanish afforded a larger weight of meats per acre:

|                   |      |     |
|-------------------|------|-----|
| McGovern .....    | 871  | 87  |
| Red Spanish ..... | 1005 | 100 |

In 6 out of 9 experiments Tennessee Red was surpassed by Red Spanish on the basis of unhulled nuts:

|                     |      |     |
|---------------------|------|-----|
| Tennessee Red ..... | 1079 | 86  |
| Red Spanish .....   | 1252 | 100 |

In all experiments, except one, the yield of meats from Red Spanish was greater than the yield from Tennessee Red.

In 4 out of 6 tests Virginia Bunch was exceeded in yield of unhulled nuts by Red Spanish:

|                      |      |     |
|----------------------|------|-----|
| Virginia Bunch ..... | 1193 | 86  |
| Red Spanish .....    | 1397 | 100 |

In every case where the meats were separated Red Spanish afforded a larger yield of meats per acre than did Virginia Bunch.

#### DESCRIPTION OF VARIETIES OF PEANUTS.

The many different names used both for distinct varieties and for those whose characters do not mark them as distinct are confusing. It is unfortunate that some seedsmen and farmers, zealous to sell seed, should attach new names to old varieties, and thereby confuse and mislead the buyer. There is no objection to a grower attaching some distinguishing mark to a greatly improved strain or to a distinctly new variety, but it should be shown that he has improved the old variety or found a distinctly new one. If the originator would tell the true source of his improved strain or the origin of his new variety, this knowledge would help the farmer to appreciate more fully the characters for which the new strain or variety is notable. A name should distinguish the variety from other varieties. The great number of variety names, without distinguishing characters, is a source of much confusion.

The common varieties of peanuts may be divided into two great classes; those having an upright, bunchy habit of growth, and those having a low spreading or "running" habit.

Among the common varieties of the first group are the White Spanish, Red Spanish, Valencia, Virginia Bunch and Tennessee Red. Those having the spreading habit are North Carolina, sometimes called African, Virginia Runner and McGovern. In this division may also be included one of the varieties called Jumbo, which name is listed by some seedsmen as a bunch and by others as a runner.

*White Spanish.*—This variety has an erect habit of growth, is about 10 to 14 inches high when grown on average soil, is early, and grows an abundance of foliage. Its pods grow in a cluster about the base of the stems and adhere well to the vines when they are harvested.

The pods are small and require about 461 unshelled peanuts to weigh a pound. The peas vary in color

from light pink to cream. The unhulled nuts yield 75.1 percent of meats. The average amount of oil contained in a ton (but not all capable of being extracted) is 702 pounds, which is more than the amount of oil found in a ton of any other variety. The pods of both Spanish varieties are assumed to weigh 30 pounds per bushel, though 28 pounds are sometimes sold as a bushel. This is probably the most productive variety.

*Red Spanish.*—This variety in habit of growth is very much like the White Spanish. Its pods are larger, 390 weighing a pound. It shells out about 72 percent of light, red nuts. The amount of oil per ton is 693 pounds, which is the second largest amount obtained.

*Valencia.*—This variety, sometimes called Improved Valencia, is erect in habit and grows from 12 to 24 inches high. Its pods grow close to its roots and cling poorly to the vines when they are pulled up.

The pods are medium in diameter and are long, with two, three or four peas crowded closely together. About 266 pods weigh a pound. The peas are red and small, and form about 60 percent of the weight of the pods. In unshelled perfect pods the percentage of oil was 28.6, or 572 pounds per ton. A bushel weighs about 24 pounds.

*Virginia Bunch.*—This is a semi-erect variety. Its pods cluster about the base of the stems; they are bright, nearly smooth, and require about 283 to weigh a pound. They contain one, two and sometimes three pale or pinkish peas. The percentage of meats found in the unshelled pods was 46, and of oil 21.2. The total oil contained per ton of unshelled peanuts was only 424 pounds. The usual weight per bushel is 22 pounds.

*Tennessee Red.*—This variety resembles the Spanish varieties in type of plant. It is medium early, and its pods cling to the stems when they are pulled up. The pods have two or three peas, and about 246 unshelled peanuts are required to weigh a pound. It shells out 56 percent of meats. The peas are red. The percentage of oil in the unshelled pods is 23.6, or 527 pounds per ton. A bushel is usually assumed to weigh 22 pounds.

*North Carolina.*—This variety, sometimes called African or Wilmington, has a low spreading habit of growth. The variety called McGovern or Florida seems to be nearly the same as this, with probably this differ-

ence, that the McGovern seems to have more resistance to rotting of the nuts and to leaf spot. The stems of McGovern are long, slender and spreading.

The pods of the North Carolina are small, and do not cling well to the stems when the vines are pulled up. A pod usually has two small reddish peas. This variety is late. It required about 440 pods to weigh a pound, and yielded about 66 percent meats. The percentage of oil found was 26.2 percent, or 524 pounds in a ton of unshelled pods. A bushel is assumed to weigh 22 pounds.

*Virginia Runner.*—This variety is sometimes called Virginia Improved. It resembles, in habit of growth, the North Carolina or African variety, except that its pods are considerably larger. Its pods and peas, in size and color, closely resemble those of the Virginia Bunch variety; 279 pods weighed a pound, and yielded 53.1 percent of meats. This variety yields 24.6 percent of oil, or 493 pounds per ton.

*Jumbo.*—Under this name, seedsmen have listed a running Jumbo and a bunch Jumbo. The two resemble each other in every respect, except in habit of growth of vines. In habit of growth and size of pods these two forms closely resemble the Virginia Bunch and Virginia Runner. Of the Jumbo samples studied, 276 of the pods weighed a pound, and yielded only 41 percent of meats. It seems that the name Jumbo has been applied to large nuts, and does not represent a distinct variety. A Jumbo may be a Virginia Bunch or a Virginia Runner, or even a Tennessee Bunch.

The varieties grown under the name of Jumbo averaged lowest in oil, 17.7 per cent, or 354 pounds of oil in a ton of unshelled peanuts.

Based on the average percent of oil and of sound peas, the varieties of unshelled peanuts take the following rank in pounds of oil per ton:

|                             |     |
|-----------------------------|-----|
| White Spanish .....         | 702 |
| Red Spanish .....           | 693 |
| Valencia .....              | 572 |
| McGovern .....              | 548 |
| Tennessee Red .....         | 527 |
| North Carolina Runner ..... | 524 |
| Virginia Runner .....       | 493 |
| Jumbo .....                 | 354 |



## OIL PRODUCTION AND YIELD AS REPORTED BY THE OIL MILLS.

From a questionnaire that was sent to a number of Alabama oil mills known to be crushing peanuts, the following facts were learned. These manufacturers are using the Anderson Expeller type of mill, which has a capacity ranging from 400 to 600 gallons of oil per day of 24 hours. The operators of these mills report that this machinery extracts from 92 to 95 percent of the oil contained in the peanuts.

They report from a ton of peanuts of the Spanish varieties, from 600 to 700 pounds of oil and from 1200 to 1300 pounds of peanut cake or meal. A ready sale for all peanut products is reported by the mills.

Some mills report that the color of the shelled peas is a matter of no importance. Others express a preference for "white" peanuts. All mills except the one at Brundidge prefer the White Spanish variety. The Brundidge mill prefers the North Carolina Runner, stating that its yield is higher than the yield of Spanish. The yield of peanuts in the locality of the mills in 1916 was estimated by the mills at 850 pounds of nuts per acre, and the average price for the past season was placed at about 3 cents per pound.

## PREPARATION AND PLANTING.

Peanuts are grown on a wide range of soils, sandy or loamy being best adapted. Soils having considerable clay and lime produce good crops. A hard, compact soil is poorly adapted because the pod stems, called "needles" or "pegs," do not penetrate its surface. Poorly drained and sour land will not give good yields. The mechanical condition of the soil is important. A liberal amount of humus, and lime and available plant food is essential to securing the largest yields.

Land intended for peanuts and not occupied by a winter crop should be plowed in the early spring. In case it is so occupied, the soil should be plowed as soon as the spring crop is removed. Where there is considerable trash on the surface from some preceding crop, this trash should be plowed under before planting in time for it to rot or at least to permit the soil to settle. About the same treatment given to land to prepare it for cotton is sufficient to prepare it for peanuts.

The importance of planting peanuts after a clean cultivated crop should not be overlooked. If the preceding crop had an abundance of grass and weeds it



will be difficult to keep the peanut crop clean. It is not good practice to plant peanuts after peanuts. Some regular system of rotation of crops should be followed.

Planting a row of peanuts in the middles of corn rows, as practiced in southeast Alabama, has the advantage of making a peanut crop with little expense except the cost of the seed and the planting. The peanuts are cultivated at the same time the corn is cultivated. This is a satisfactory practice where the peanuts are gathered by hogs (except that it increases the amount of fencing); but when they are gathered for commercial purposes, the corn plants hinder the harvesting.

Peanuts should not be planted on high beds because such beds dry out quickly, which condition tends to make a poor stand.

For the bunch variety, the rows may be made from 2½ to 3 feet wide, that is just wide enough to permit easy cultivation with ordinary cultivating implements. For the running variety, the rows should be from 3 to 3½ feet wide.

The seed of the bunch varieties may be dropped from 4 to 8 inches apart in the drill. The running type may be dropped from 12 to 15 inches apart in the drill. The seeding should be so thick that the vines will nearly cover the ground when they are fully grown. Planting should not begin until the middle of the usual period for planting cotton, and for the Spanish or early maturing varieties it may continue until the first of June, or even until the middle of June. The soil should be thoroughly warm.

Allowing for faulty nuts and occasional placing of two nuts in a hill, we may conclude that about the following amounts of seed should be provided per acre:

|                                                                                     |        |
|-------------------------------------------------------------------------------------|--------|
| For Spanish varieties, rather close planting (6 x 30 in.)                           | 7 pks. |
| For Spanish varieties, thin planting (10 x 36 in.)                                  | 4 pks. |
| For North Carolina or similar running kinds, thick planting (10 x 36 in.)           | 7 pks. |
| For North Carolina or similar running varieties, rather thin planting (12 x 42 in.) | 5 pks. |

A special peanut planter, or an ordinary Cole planter and doubtless other types of one-horse planters may be used for planting shelled peanuts. The seed should be covered from 1¼ to 2 inches deep.

The varieties of peanuts that have large pods should be shelled in order to secure a good stand. Such varieties as the White and Red Spanish may be planted without shelling the nuts. However, shelling of any va-

riety insures more prompt germination and a better stand.

#### CULTIVATION.

It is well to harrow the rows to destroy the young weeds and grass before the peanuts come up. One cultivation or more with a weeder or light spike-tooth harrow should be given before the plants get much growth. Following this time, the ordinary implements used for the cultivation of cotton may be employed. The cultivation may continue close up to the plant, until the fruit stems begin to form, after which time the cultivating implements should not run close to the row. The covering of the blooms with dirt is unnecessary.

#### HARVESTING.

The tops of the vines usually turn yellow and some of the leaves begin to drop off when the peanuts are ripe. If the harvesting is delayed the early maturing nuts of the Spanish varieties may sprout in the ground.

The harvesting may be done by hand or plow. Varieties whose pods cling well may be pulled up from very sandy land by hand. This is a slow method. An ordinary turning plow with its mold board removed to avoid covering the plants may be employed to raise the plants. The bunches may be collected in piles with an ordinary hay fork.

#### CURING AND PICKING.

The plants are usually left on the ground, after harvesting, for at least two or three hours. They should then be stacked. This is done by firmly setting up stakes about 6 feet high, at the bottom of which are nailed two or three cross pieces 3 or 4 feet long. Around this stake the plants are stacked with the vines exposed, and the nuts inward. Ventilation is thus secured for the peanuts within, while they are protected from the weather by the vines.

From 15 to 20 such stacks will be necessary for one acre. The stacks should be capped with grass and remain 3 or 4 weeks in the field until the pods have become dry. They are then ready for a picker.

Some of the Florida growers have made use of a curing shed. On the posts are spiked cross timbers and on these timbers horizontal poles are placed suf-

ficiently close to support the green peanut vines. From one floor of poles to the next is kept a vertical distance of about 5 or 6 feet. This space allows complete ventilation and the peanuts remain spread upon the poles until they become thoroughly dried. This method of curing secures a better quality of hay and bright pods.

The picking of the peanuts off the stems by hand is slow and expensive. In a community where a large acreage is planted a custom picker may be operated profitably. There are several types which are now offered on the market. One type depends for the removing of the nuts from the vines on the use of a system of vibrating wire screens, and is used exclusively for peanut *picking*. The other type of picker is an ordinary grain *thresher* with a special cylinder and concave for peanuts. This last machine readily removes the nuts and makes them ready for oil mill purposes, but according to the statement of the president of one of the peanut oil mills in Alabama, the peanut thresher breaks up the pods and injures the nuts for planting purposes.

#### PEANUT HAY AND STRAW.

Peanut vines make a fine quality of hay if cut before the leaves drop. Their chemical composition is nearly that of alfalfa hay. Valencia, Virginia Bunch, and the Spanish varieties are the best suited for hay making on account of their upright habit of growth, which makes them easy to mow.

Peanut straw (the cured peanut plant after the filled pods have been picked off) has a larger proportion of woody stems and a smaller proportion of leaves than peanut hay, which render the former somewhat less nutritious than peanut hay.

#### CHEMICAL COMPOSITION OF PEANUT STRAW.

The chemical composition of peanut straw, as reported by the Chemical Department of this Station, is as follows:

Water, 10.72 percent; ash, 6.03 percent; crude protein, 10.69 percent; crude fat, 1.66 percent; crude fiber, 29.5 percent; carbohydrates, 41.39 percent.

Its composition shows that it carries 1.2 percent potash, and 0.50 percent phosphoric acid.

## RESIDUAL FERTILIZING EFFECT OF PEANUTS.

This table records the result of a test made to show the fertilizing effect of peanuts on following crops. As indicated in the table, peanuts were harvested in different ways, and the succeeding yields of rye and sorghum hay are compared with the hay yields from a plot on which corn had been grown.

TABLE VIII. *Residual Fertilizing Effect of Peanuts Compared With Corn. (\*)*

| Crop—Summer of 1899              | Succeeding Crops              |                              |
|----------------------------------|-------------------------------|------------------------------|
|                                  | Rye<br>Winter of<br>1899-1900 | Sorghum<br>Summer of<br>1900 |
|                                  | Lbs. per Acre                 | Lbs. Per Acre                |
| Spanish peanuts—nuts harvested - | 1080                          | 4480                         |
| Spanish peanuts—grazed by hogs - | 4280                          | 4000                         |
| Running peanuts—turned under --  | 2582                          | 6320                         |
| Corn—ears pulled -----           | 1080                          | 5040                         |

The peanut plots gave a yield of rye higher than that of the non-legume plot in two instances; where the peanuts were grazed and the plot got the benefit of the droppings from animals, and where the luxuriant growth of vines were turned under on account of the running peanuts failing to make.

Two of the peanut plots yielded less sorghum hay than did the corn plot, and only on the plot on which the vines were turned under did the yield of this second succeeding crop prove greater than that following corn.

The conclusion is that a crop of peanuts harvested in the usual way for seed does not improve the soil for a succeeding crop.

## INOCULATION OF PEANUTS.

The peanut is a legume, roots of which should be abundantly supplied with tubercles to make sure that it makes use of the nitrogen of the air rather than that of the soil. So far as the observations of the writers go, the peanut plant on Southern soils is naturally stocked with tubercles. Hence artificial inoculation, either with soil or with pure cultures, seems to be a useless expense.

Probably the usual occurrence of tubercles on the roots of the peanut plant results from natural inoculation carried on the seed in the dust from the old field. This dust from the hulls comes in contact with the

(\*) Bul. 104, Alabama Experiment Station.



shelled nuts in any process of shelling, and is of course still more abundant if unshelled nuts are planted.

Experiments made on sandy land on the farm of the Alabama Experiment Station, at Auburn, showed no increase in yield from inoculating peanuts with appropriate soil, and no apparent increase in the number of tubercles per plant.

#### DISEASES OF PEANUTS.

*Leaf spot*, which appears as a small, brown spot on the leaves and stems, is caused by a fungus disease (*Cercospora personata*). It usually attacks the grown leaves, though it may attack the young ones causing them to fall off, thereby reducing the value of the hay and the yield of peanuts.

This leaf spot fungus may be carried from one year to the next on old peanut leaves and stems. Crop rotation and plowing under all old vines and stems are, therefore, recommended as good farm practice to lessen the amount of the disease in a succeeding peanut crop.

*Sclerotial rot*, (caused by *Sclerotium Rolfsii*) attacks the roots and peas, and destroys the pods. The top of the plant may be healthy in appearance, but when it is pulled up, many of its pods may be found completely rotten. The rotten pods may appear wet or dry, as other organisms of decay may have become associated with the decayed nuts.

No means of combatting sclerotial rot is known.

*Red rot* attacks the pods of the peanut and causes them to appear brown or reddish. The crop should be dug as soon as it matures to avoid loss from this disease. (See Alabama Station Bulletin No. 180).

#### AVERAGE YIELD OF PEANUTS.

According to figures furnished by the Bureau of Crop Estimates of the United States Department of Agriculture, the average yield of peanuts for the United States for the past five years has been 38.6 bushels per acre. For the same period, the Southern States averaged as follows:

| State          | Bushels | State       | Bushels |
|----------------|---------|-------------|---------|
| North Carolina | 42      | Alabama     | 37      |
| South Carolina | 45      | Louisiana   | 32      |
| Georgia        | 40      | Mississippi | 34      |
| Florida        | 36      | Texas       | 33      |
| Tennessee      | 48      | Oklahoma    | 38      |



As a rule, the yield is very nearly in proportion to the thickness of the stand. Especially is this true with the Spanish varieties. The largest yield on record is one made on the farm of Dr. J. F. Yarbrough, at Columbia, Alabama. The yield, as reported by Dr. Yarbrough, on the basis of 24 pounds of Spanish peanuts per bushel, was  $214\frac{1}{2}$  bushels on an acre. On the basis of 28 pounds per bushel the yield was 183.9 bushels. These peanuts were planted in rows 17 inches apart. The nuts were very carefully placed 4 inches apart in the drill. Cultivation was chiefly with a weeder and by hand. The soil was a deep, loose sand, fertilized per acre as follows:

1,000 pounds ground limestone.

1,600 pounds 16 percent acid phosphate.

1,600 pounds kainit.

**BULLETIN No. 195**

**JUNE, 1917**

TECHNICAL BULLETIN No. 2

**ALABAMA**  
**Agricultural Experiment Station**  
**OF THE**  
**Alabama Polytechnic Institute**  
**AUBURN**

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**The Cause of the Disappearance of Cumarin, Vanillin, Pyridine and Quinoline in the Soil**

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**By**  
**WILLIAM J. ROBBINS, Botanist**

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**1917**  
**Post Publishing Company**  
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# THE CAUSE OF THE DISAPPEARANCE OF CUMARIN, VANILLIN, PYRIDINE AND QUINOLINE IN THE SOIL<sup>1</sup>

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By

WILLIAM J. ROBBINS, Botanist,  
Alabama Agricultural Experiment Station.

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Since the proposal of the soil toxin theory of soil fertility by DeCandolle (4) <sup>2</sup> in 1832, and its further elaboration in recent years by the Bureau of Soils of the U. S. Department of Agriculture, evidence has been offered to support or discredit it along several lines. One of these has been the demonstration that organic substances, either found in the soil or reasonably assumed to be there, are toxic to crop plants in water culture. As a further step in this same direction, the effect on plants of these substances, when added to the soil, has been studied.

The results obtained when the compounds are added to the soil have been conflicting. Some investigators have found that the compounds which are toxic to plants in water culture are decidedly harmful when added to the soil. They have also found that the compound and its toxic effects persist for a considerable space of time. Others have found that the same compounds have little or no toxic action in the soil or even prove decidedly beneficial to the growth of the plants. They have also found that the compounds disappear rapidly in the soil.

The work recorded in the following pages was undertaken to determine the cause of the disappearance of these compounds in the soil. With a clear understanding of why they disappear in one soil, it would appear possible to explain why they persist in other soils and to examine intelligently methods for eliminating them from soils in which they are known to exist and in which they may be a contributing cause to infertility.

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<sup>1</sup> The writer wishes to express his indebtedness to Mr. A. E. Elizondo for careful and conscientious assistance.

<sup>2</sup> Reference is made by number to "Literature Cited," p. 63.

LITERATURE <sup>3</sup>

Duggar (5) states that "wheat in paraffined pots containing rich garden loam is practically unaffected by pyridine at the enormous rate of 8,000 parts per million, this solution being used to moisten the soil to 60 percent of its water holding capacity."

Davidson (3) studied the effect on the growth of wheat of cumarin and vanillin when added to Dunkirk clay loam. It was found that 180 parts per million <sup>4</sup> of cumarin, or 600 parts per million of vanillin depressed the yield somewhat. Davidson concludes that even this effect is on the soil and not on the plant.

Skinner (28) in pot experiments, found that vanillin added to the soil before potting, at a concentration of 500 parts per million, was harmful to wheat plants grown in infertile Florida sandy loam soil and infertile Susquehanna sandy loam, but had no effect on wheat grown in fertile Hagerstown loam. Vanillin added to plots of the experiment farm of the Agricultural Department at Arlington at the rate of 285 pounds per acre stunted the growth of cowpeas, garden peas and string beans. The same investigator found vanillin present in the soil of these plots six months after its application, and demonstrated by pot experiments that the compound still injuriously affected the growth of plants.

Fraps (6) has found that vanillin at a concentration of 100 parts per million is injurious to corn or oats in but one of eight soils, but is injurious in all cases at a concentration of 200 parts per million. Cumarin was injurious at 100 parts per million in six out of nine experiments; at 200 parts per million in five out of seven, and at 300 parts per million in one of two. He also found that the vanillin and cumarin rapidly disappeared during the course of the experiment.

Funchess (7) found that pyridine and quinoline in Norfolk sandy loam or Cecil clay in pots had little harmful effects or proved decidedly beneficial to the growth of corn or oats. Vanillin and cumarin had

<sup>3</sup> Only the literature dealing with the effect on plant growth of vanillin, cumarin, pyridine and quinoline when added to the soil is cited here. In water culture, according to Schreiner, Reed and Skinner (22), vanillin is harmful to wheat at a concentration of 1 part per million; cumarin, at 1 part per million; pyridine, at 50 parts per million and quinoline at 5 parts per million.

<sup>4</sup> Expressed in parts per million of air-dry soil.



little or no toxic effect. In all cases the beneficial effect was intensified, or the toxic effect entirely eliminated when the pots were allowed to stand for a period of about six months after the application of the compounds.

Upson and Powell (30) report that vanillin in the soil, even at a concentration of 1000 parts per million, shows very little harmful effect on the growth of wheat. Cumarin acted quite differently in the soil from what it did in water culture.

## EXPERIMENTAL

### SOILS USED

The soils used were a Norfolk sandy loam from what is known as the "Culler's rotation plot" and a sandy loam from plots on the Experiment Station Farm which have received annual applications of ammonium sulfate. The former soil was practically neutral in reaction, and is of fair fertility. The latter was decidedly acid. Clover grows poorly upon it. The first soil is similar to one used by Funchess in which the results noted above were obtained.

### CHEMICALS USED

The vanillin, cumarin, pyridine and quinoline were Merck's C. P. chemicals.

### THE EFFECT OF VANILLIN, CUMARIN, PYRIDINE AND QUINOLINE ON THE MICROORGANISMS OF THE SOIL

Nine kilograms of air dry soil (Norfolk sandy loam) were placed in two gallon pots. The pots were thoroughly watered with tap water and allowed to stand for thirty days. At the end of that time the soil was removed from the pots and spread on sterile paper. The compounds were added, thoroughly mixed with the soil by means of a sterile spatula and the soil repotted. The vanillin and cumarin were added at the rate of 9 gms. per pot; the pyridine and quinoline at the rate of 14 cc. per pot. Each treatment was made in duplicate. The soil in two pots was removed, mixed and repotted without treatment. These two pots served as checks. An attempt was made to keep the water content uniform throughout the series by weighing about once a week and making up the loss with distilled water. The number of microorganisms devel-

oping in the pots was determined by the methods described by Brown (2), using his albumen agar. Each soil was plated in duplicate, using dilutions of 1 to 20,000 and 1 to 200,000, as described by Brown.

*The Number of Microorganisms.* The number of microorganisms developing in the pots are given in Table I.

TABLE I—*Microorganisms in Millions per 0.25 gm. of Air Dry Soil. Soil Potted June 30th. Compounds Added to Pots July 29th.*

| Treatment     | July 13 | July 26 | Aug. 3<br>5 days<br>after<br>treat-<br>ment | Aug. 15<br>17 days<br>after<br>treat-<br>ment | Aug. 30<br>32 days<br>after<br>treat-<br>ment | Sept. 27<br>55 days<br>after<br>treat-<br>ment | Oct. 22<br>85 days<br>after<br>treat-<br>ment |
|---------------|---------|---------|---------------------------------------------|-----------------------------------------------|-----------------------------------------------|------------------------------------------------|-----------------------------------------------|
| None -----    | 1.25    | 1.29    | 1.64                                        | 1.44                                          | 1.37                                          | 1.15                                           | .89                                           |
| Vanillin ---- | 1.35    | 1.39    | .42                                         | 10.63                                         | 11.84                                         | 2.74                                           | 1.05                                          |
| Cumarin ----  | 1.18    | 1.72    | 3.08                                        | 44.55                                         | 5.42                                          | 2.91                                           | 1.52                                          |
| Pyridine ---- | 1.27    | 1.25    | 1.97                                        | 31.13                                         | 5.73                                          | 2.22                                           | 1.18                                          |
| Quinoline --  | 1.11    | 1.33    | .60                                         | 1.12                                          | 3.05                                          | 6.34                                           | 10.21                                         |

From Table I it can be noted that in all cases the compounds have caused a marked increase in the numbers of microorganisms. In the case of vanillin and quinoline this occurs after an initial depression. In the case of pyridine and cumarin no such depression is evident. It should be remembered, however, that if a determination had been made sooner after the addition of the compound to the pots, a depression in numbers might also have been found in the case of the latter two compounds.

The maximum number of organisms developing in four days at room temperature on the medium used is 178.20 millions per gm. of air dry soil in the cumarin treated pots 17 days after treatment. This is almost 40 times as many organisms as were present in the untreated pots. The maximum number of organisms observed was 218.21 millions in one of the cumarin treated pots at the end of 17 days. The actual number in any of the treatments may have been larger than is indicated in the table as the greatest increase may have occurred in the case of some of the treatments at a time which fell between determinations.

The maximum number of organisms occurs at different times depending on the treatment. In the cumarin and pyridine treated soils the organisms reach their

maximum numbers first, followed by those in the vanillin and quinoline treated soils. Quinoline depresses the number of microorganisms for the longest period, a period of 17 days. Its odor also persisted longest, being still evident 55 days after the treatment.

*The Flora of the Plates.* No complete data on the flora of the plates was recorded. It was noted, however, that the increase in the numbers of microorganisms was due chiefly to the development of bacteria and not to an increase in the numbers of Actinomyces. As far as the medium would allow differentiation, the number of Actinomyces colonies previous to treating the soil was 30-40 per plate at a dilution of 1 to 20,000 or about 20-30 percent of the total number of microorganisms. The number of Actinomyces colonies per plate at the 1-20,000 dilution after the soil had been treated with the compounds is given in Table II. Each figure is the average of a count of two plates from each of two duplicate pots.

TABLE II. *Number of Actinomyces Colonies Appearing on the 1 to 20,000 Dilution Plates.*

| Treatment     | August 3rd 5 days<br>after treatment        |                                            | August 15th—17 days<br>after treatment      |                                            | August 30th—32 days<br>after treatment      |                                            |
|---------------|---------------------------------------------|--------------------------------------------|---------------------------------------------|--------------------------------------------|---------------------------------------------|--------------------------------------------|
|               | No. of<br>Acti-<br>nomyc-<br>es<br>colonies | Percent-<br>age of<br>total or-<br>ganisms | No. of<br>Acti-<br>nomyc-<br>es<br>colonies | Percent-<br>age of<br>total or-<br>ganisms | No. of<br>Acti-<br>nomyc-<br>es<br>colonies | Percent-<br>age of<br>total or-<br>ganisms |
| None-----     | 46                                          | 30                                         | 72                                          | 36                                         | 38                                          | 29                                         |
| Vanillin ---- | 4                                           | 11                                         | 0                                           | 0                                          | 0                                           | 0                                          |
| Cumarin ----  | 21                                          | 7                                          | 17                                          | 1.3                                        | 87                                          | 17                                         |
| Pyridine ---- | 66                                          | 35                                         | 179                                         | 23                                         | 207                                         | 41                                         |
| Quinoline---  | 11                                          | 21                                         | 17                                          | 10                                         | 6                                           | 0.8                                        |

From the data given in Table II it is evident that the number of Actinomyces, both actual and relative to the total number of organisms, decreased markedly in the pots treated with vanillin, cumarin and quinoline. In the pyridine treated pots the actual number of Actinomyces increased. The bacteria, however, in the pyridine treated pots increased in proportion, as is indicated by the fact that the percent of Actinomyces colonies did not increase decidedly.

By comparing the figures in Table I and Table II we find a more or less close correlation between the lowest percentage of Actinomyces and the greatest number of microorganisms. In fact, at the time of

maximum increase in numbers of microorganisms in the cumarin, vanillin, and quinoline treated soils the Actinomyces have practically disappeared, reappearing later with the decrease in numbers as is shown for cumarin in Table II, and as was observed for quinoline and vanillin at a date later than August 30. The significance and cause of this is not clear.

*Discussion.* The increase in numbers of microorganisms observed in the treated pots appears to be much similar to that found in "partial sterilization" with steam, carbon disulfide, toluol, etc., by Hiltner, Russel and Hutchinson and others. They have found in general that treatment of the soil by sterilizing agents, in quantity or degree insufficient to cause complete sterility, frequently produces an enormous temporary increase in the microscopic flora of the soil. The increase is often preceded by a depression. Buddin (1) has studied the effects of pyridine. He found a marked effect, obtaining a maximum number of 3,500 millions of organisms in the pyridine treated pots when the check gave but 13 millions.

The explanations offered for this phenomenon have been various. Russell and Hutchinson (18) have stated that the increase in the number of bacteria is due to the fact that the antiseptic destroys the bacteria consuming protozoa. Other explanations offered by various investigators are summarized by Lipman (12) as "(1) increase in available food for bacteria; (2) rendering soil toxins insoluble; (3) destroying bacterio-toxins; (4) acceleration of biological processes." Buddin (1) suggests for pyridine that pyridine affords a magnificent diet for bacteria, and provides the simple case of two or three species feeding directly on the substance itself or its decomposition products. Davidson (3) observed a growth of molds and fungi in a solution containing 200 parts per million of cumarin which had stood for some time and suggests that microorganisms may destroy cumarin and vanillin in the soil. (Funchess (8, 17) has found that pyridine and quinoline are apparently nitrified in the soil. These facts and suggestions, as well as others not mentioned, appeared to indicate that Buddin's explanation might also hold for vanillin, cumarin and quinoline. In order to determine whether microorganisms acted on these compounds in the soil, the following method was used:



# COMPARATIVE EFFECT ON PLANT GROWTH OF TOXINS IN STERILE AND INOCULATED SOIL.

In each of 30 two-liter bottles 500 grams of air dry soil were placed. This soil came from the ammonium sulfate manured plots, referred to above. Ninety cc. of tap water were added to each of the bottles. To six of the bottles 0.5 gm. of vanillin was added and to six others 0.5 gm. of coumarin. The 30 bottles were plugged with cotton and sterilized in an autoclave for 3 hours at 15 lbs. pressure. After sterilization 0.5 cc. of pyridine was added to 6 of the bottles and 0.5 cc. of quinoline to 6 others. These compounds were added by means of sterile pipettes. The remaining six bottles received no treatment. Half, 3, of each set was inoculated by adding about 2 cc. of a suspension of normal soil in sterile water and all were incubated in a dark cupboard at room temperature for 57 days. At the end of that time ten wheat grains, sterilized by Wilson's method (31) were dropped into each bottle. Sixteen days after planting the wheat the sterile bottles were tested for sterility by plating some of the soil in Brown's albumen agar. All were sterile save one of the quinoline series which contained fungi. At the same time the wheat plants were removed from the bottles and the tops and roots measured. Due to the difficulty in removing the plants from the narrow necked bottles considerable of the roots was lost in all cases in which they had penetrated the soil. The results are given in Table III. The method used in growing the plants and the results with the set treated with pyridine are shown in Plate I, figure 1.

TABLE III. *Growth of Wheat in Sterile and Inoculated Soil Which Had Been Incubated for 57 Days.*

| Treatment     | Number of plants from 30 seeds |            | Average length of tops in centimeters |            | Average length of roots in centimeters |            |
|---------------|--------------------------------|------------|---------------------------------------|------------|----------------------------------------|------------|
|               | Sterile                        | Inoculated | Sterile                               | Inoculated | Sterile                                | Inoculated |
| Coumarin----  | 0                              | 22         | 0                                     | 12.3       | 0                                      | 10.5       |
| Pyridine----  | 18                             | 24         | 5.3                                   | 24.1       | 3.7                                    | 8.1        |
| Vanillin----  | 24                             | 25         | 2.6                                   | 17.3       | 1.2                                    | 10.4       |
| Quinoline---- | 0                              | 5          | 0                                     | 20.2       | 0                                      | 7.0        |
| None-----     | 25                             | 20         | 6.9                                   | 19.2       | 3.3                                    | 15.4       |

From the data it is evident that inoculating the untreated steamed soil with an infusion from normal soil



produces a decided increase in the growth of wheat. Explanations for this effect based on increased plant food produced by bacterial action might be offered. The appearance of the roots of the plants, however, make it evident that the steam heating of the soil had produced toxic material and that the inoculation had caused its disappearance, or nullified its effect.

Inoculation has also markedly improved the growth of the plants in pyridine, quinoline, vanillin, and cumarin treated soils. The production of toxic conditions in the steamed soil makes it more difficult to determine whether the improved growth in these cases is caused by the action of the microorganisms on the toxic material produced by steaming or by their action on the compounds. The fact, however, that the toxic effect of the compounds is evident on the germination (cumarin and pyridine) and on the growth (cumarin, pyridine and vanillin) in the sterile soil while in the inoculated soils this effect has disappeared almost completely in the case of pyridine and vanillin, and very largely in the case of cumarin would lead us to believe that microorganisms had acted on the cumarin, vanillin and pyridine. This is also substantiated by the fact that no odor of pyridine, cumarin nor vanillin remained in the soil removed from those bottles which were inoculated while it was still present strongly in the sterile bottles. The case of quinoline may be considered doubtful. The odor of quinoline still clung to the soil in both sterile and inoculated bottles.

That microorganisms have neutralized the toxicity of the vanillin, cumarin and pyridine and also acted on the quinoline is shown more clearly by the following:

The soil removed from the bottles was dried for four days. It was then placed in tumblers and brought to a uniform water content. The soil from each bottle filled two tumblers. Ten wheat seeds were planted in each tumbler and allowed to grow for 11 days. Of course, the soil from all the bottles, both sterile and inoculated, was inoculated by the handling. The results are given in table IV; in Plate I, figures 2 and 3, and in Plate II, figures 4, 5 and 6.

TABLE IV. *Growth of Wheat in Soil From Sterile Bottles and Inoculated Bottles.*

| Treatment | Number of plants from 60 seeds |                              | Average length of tops in centimeter |                              | Green weight of tops per 10 plants in grams |                              | Dry weight of tops per 10 plants in grams |                              |
|-----------|--------------------------------|------------------------------|--------------------------------------|------------------------------|---------------------------------------------|------------------------------|-------------------------------------------|------------------------------|
|           | Soil from sterile bottles      | Soil from inoculated bottles | Soil from sterile bottles            | Soil from inoculated bottles | Soil from sterile bottles                   | Soil from inoculated bottles | Soil from sterile bottles                 | Soil from inoculated bottles |
| Cumarin.  | 10                             | 54                           | 4.0                                  | 17.0                         | 0.250                                       | 1.049                        | 0.035                                     | 0.126                        |
| Pyridine. | 43                             | 34                           | 15.8                                 | 15.9                         | 1.005                                       | 1.120                        | 0.115                                     | 0.115                        |
| Vanillin. | 46                             | 47                           | 10.0                                 | 17.2                         | 0.525                                       | 1.087                        | 0.077                                     | 0.131                        |
| Quinoline | 39                             | 34                           | 7.4                                  | 16.4                         | 0.42                                        | 1.002                        | 0.045                                     | 0.109                        |
| None----  | 40                             | 46                           | 14.5                                 | 14.6                         | 0.806                                       | 0.950                        | 0.099                                     | 0.113                        |

From the growth of the wheat plants in the untreated soil from the sterile and inoculated bottles it is evident that the difference between the two has largely disappeared. This is perhaps due to bacterial action in the soil which came from the sterile bottle. Less marked differences than are given in Table III are also noted between the soil from the sterile and inoculated bottles in the case of all the compounds. This is particularly true of pyridine. Comparing the growth of the wheat in the treated and untreated soils it is evident, however, that the toxic effect of cumarin, vanillin and quinoline is still present in the soil from the sterile bottles. In the soil from the inoculated bottles the growth in the vanillin and cumarin treated soils is as great if not greater than that in the untreated. The toxic effect of the quinoline has also largely disappeared. It would seem clear then that the microorganisms have in some way neutralized the toxicity of vanillin, cumarin, pyridine and quinoline.

*Discussion.* The development of material toxic to higher plants in soil which has been steam heated has been observed by others. Pickering (13, 14, 15, 16) observed that the germination and the growth of plants is retarded in heated soils. He believes that the toxic substances formed are organic in nature. Pickering also found that the toxic qualities of heated soils are reduced on storing them under moist aerated conditions. This he believes is not due to bacterial action but to chemical changes in which the action of water is particularly concerned. Russel and Petherbridge (19) state that there is no evidence that the active substances in steam heated soils are necessarily

organic, but suggest that ammonia and other inorganic substances may be responsible for the toxicity. They also state that they could obtain no definite proof that the harmful effect on germinating seeds passes off after a time. Seaver and Clark (20, 21) emphasize the fact that the decomposition products found in heated soil may be toxic to higher plants but favorable for the development of *Pyronema* or other moulds. Schreiner and Lathrop (27) found that in steam heated soils there was an increase in water soluble constituents and in acidity. They seem inclined to believe that the toxicity of the heated soils to plant growth is due to the development of organic harmful material. Johnson (11) states that ammonium compounds develop in heated soils and are responsible for the harmfulness of the soil to green plants. The writer's results do not indicate whether the toxic material formed in the soil used in the experiment noted above is organic or inorganic. They do show, however, that the toxicity has been largely destroyed by the action of microorganisms.

The results also show that under the conditions of the experiment and in the soil used microorganisms have largely neutralized or destroyed the toxicity of vanillin, coumarin, pyridine and quinoline. The probable method by which this neutralization is accomplished is indicated in the following section.

#### BACTERIA FEEDING ON VANILLIN, CUMARIN, PYRIDINE AND QUINOLINE.

As there seemed no doubt but that microorganisms were instrumental in destroying the toxicity of the four compounds used attempts were made to isolate the organisms responsible.

*Vanillin.* A nutrient solution was prepared containing vanillin as the only source of carbon.<sup>5</sup>

To 50 cc. of this solution, after sterilization, were added a few grains of soil from a vanillin treated pot used in the experiments reported above. In a few days the cloudy appearance of the medium showed a heavy

<sup>5</sup> This solution contained:

|                                 |      |     |
|---------------------------------|------|-----|
| NaNO <sub>3</sub>               | 0.1  | gm. |
| K <sub>2</sub> HPO <sub>4</sub> | 0.1  | gm. |
| MgSO <sub>4</sub>               | 0.05 | gm. |
| NH <sub>4</sub> Cl              | 0.1  | gm. |
| KCl                             | 0.05 | gm. |
| Vanillin                        | 0.1  | gm. |
| H <sub>2</sub> O distilled      | 200  | cc. |

multiplication of bacteria. In ten days the odor of vanillin had entirely disappeared though it was still present in the check flasks. At the end of two weeks an ether extract, evaporated to dryness, showed vanillin to have disappeared from the inoculated flasks, but to be present in the checks.

After the solution had become cloudy, as is described above, it was plated out and five isolations of bacteria were made. These all seemed to be the same organism. Using the medium given above it was found that this organism could rapidly cause the disappearance of the vanillin. Since the vanillin was the only source of carbon in the solution it is evident that the organism used it as a food.

*Cumarin.* The same procedure was followed in the search for organisms responsible for the disappearance of cumarin. The solution used was the same as that given for vanillin and contained cumarin at a concentration of about 500 parts per million substituted for vanillin. Again the cloudy appearance of the medium showed a rapid multiplication of organisms and the cumarin disappeared. The solution was plated out and six isolations were made, three of which used cumarin as a source of carbon. These three appeared to be identical organisms as far as could be judged from their growth on agar. It is understood, however, that this simple criterion is not sufficient to prove their identity. An ether extract made four days after inoculating 50 cc. of the nutrient solution containing approximately 500 parts per million of cumarin with one of these organisms, showed that the cumarin had disappeared. The temperature of incubation was about 25 to 30 degrees C.

*Pyridine.* For the isolation of organisms acting on pyridine a nutrient solution was prepared containing pyridine as the only source of nitrogen<sup>6</sup>. This solution was sterilized and, by means of a sterile pipette, sufficient pyridine was added to make a concentration of 1000 parts per million. The solution was inoculated with a small amount of soil from one of the pyridine treated bottles. The contents of the flask became

<sup>6</sup> This solution contained:

|                                       |       |     |
|---------------------------------------|-------|-----|
| K <sub>2</sub> HPO <sub>4</sub> ..... | 0.1   | gm. |
| MgSO <sub>4</sub> .....               | 0.05  | gm. |
| FeSO <sub>4</sub> .....               | 0.001 | gm. |
| KCL .....                             | 0.05  | gm. |
| C. P. dextrose .....                  | 1.0   | gm. |
| Dist. H <sub>2</sub> O .....          | 100   | cc. |



cloudy and the odor of pyridine disappeared. The solution was plated out and three isolations were made, one of which proved to be an organism which destroyed pyridine. With this bacterium present the odor of pyridine disappeared in five days and was replaced by a characteristic sour smell. As the pyridine was the only source of nitrogen in this solution it is evident that pyridine is a very favorable source of nitrogen for this organism. No attempt was made to determine whether the pyridine might not also serve as an energy source for this organism.

*Quinoline.* Attempts were also made by the same methods to secure an organism acting on quinoline, but thus far none such has been found.

These three organisms, one acting on cumarin, one on vanillin and one on pyridine are different species. They also seem to be specific inasmuch as, with the solutions and concentrations used, the organism acting on vanillin will not act on cumarin or pyridine and vice versa.

It has also been demonstrated by water culture and soil experiments that the bacterium feeding on vanillin will in pure culture entirely destroy the toxicity of vanillin for wheat plants. It has also been found that the bacterium feeding on cumarin will in pure culture destroy the toxicity of that compound for wheat plants. Further work on the physiology of these organisms is being undertaken.

*Discussion.* The enormous increase of bacteria in the vanillin, cumarin or pyridine treated soils, the disappearance of the toxic effects of the compounds in inoculated soil, but not in sterile soil, and the isolation of specific microorganisms using them as food would seem to indicate that their disappearance in the soils used in this investigation is due to the fact that they serve as very favorable food sources to definite species of bacteria. While no specific organism using quinoline was isolated, the effect of quinoline on the microorganisms in the pots and the results secured with the sterile and inoculated soils would seem to indicate that quinoline, in the soils used, suffers the same fate.

The relation of this data to the phenomena found in "partial sterilization" may be pointed out. The initial decrease in numbers noted in the vanillin and quinoline treated soils is probably due to the toxic action of the compound on some species of the bacteria present.



The later increase in numbers would seem to be due to the fact that specific organisms find the compound a very favorable food source. With the exhaustion of the compound and perhaps its decomposition products the organisms which fed upon them decrease in numbers. In view of these results it would seem advisable to re-investigate the effect of steam, carbon bisulfide and other agents which have been found to produce large increases in the number of microorganisms in the soil, bearing in mind the possibility that the increase may be due to the fact that the compounds may serve as food sources to bacteria or the treatment of the soil may make food supplies available. (Compare with Greig Smith's (9, 10) suggestions).

These results would also seem to be of considerable significance to those who are considering the soil toxin theory of soil fertility. They show that the disappearance in the soil of organic material toxic to higher plants may in some cases be accomplished by microorganisms and apparently by specific microorganisms. This view assigns the important role of destruction in the soil of such compounds as vanillin and cumarin to bacteria and not to the oxidizing action of the plant roots as might be inferred to be the case from the work of Schreiner, Reed and Skinner (23, 24, 25, 26, 29.) The persistence of the compounds on the other hand, such as occurred with vanillin in some of the soils used by Skinner (28), would appear to be due to the absence of suitable organisms or to the presence of conditions which inhibit their acting on the compounds in question.

Since the disappearance of these four compounds is due to biological factors it can be inferred that the addition of a given organic compound may produce no harmful effects in one soil and decidedly harmful effects in another depending on the presence and action of suitable organisms. This is probably the explanation for the varying and in some cases apparently conflicting results obtained with the same compound by different workers as summarized in the early part of this paper. Not only may this be inferred but it can be conceived that the same soil under some conditions of temperature, oxygen, soluble salt and water supply, etc., may allow the persistence of a harmful compound and under other conditions may eliminate it rapidly. What those conditions are can probably be discovered by a study of the physiology of the organisms involved.

## SUMMARY

1. Vanillin, cumarin, pyridine and quinoline when added separately to the soil used in these experiments at a concentration of approximately 1000 parts per million of air dry soil produce a great temporary increase in the number of bacteria which will develop on Brown's albumen agar.

2. In the case of vanillin and quinoline it is shown that this increase in numbers is preceded by a decrease.

3. The number of *Actinomyces* colonies in the soils treated with cumarin, vanillin and quinoline decreases, reaching a minimum roughly corresponding with the maximum in bacterial numbers.

4. Steam sterilizing of the soil used in these experiments produces material toxic to the growth of wheat plants. Soil microorganisms destroy the toxicity of the steamed soil under the conditions of the experiment reported.

5. The effect on the growth of wheat of vanillin, cumarin, pyridine and quinoline in sterile soil and in soil which had been sterilized, reinoculated and incubated was compared. In the inoculated soil the toxicity of the four compounds largely disappears. It persists in the sterile soil.

6. Specific bacteria were isolated from the soils used which utilize cumarin, vanillin and pyridine as food sources.

7. The bacterium feeding on vanillin will in pure culture destroy the toxicity of vanillin to wheat.

8. The bacterium feeding on cumarin will in pure culture destroy the toxicity of cumarin to wheat.

9. The increase in the numbers of bacteria in the soils treated with the four compounds mentioned and the disappearance of the toxicity of these substances in inoculated soil is therefore believed to be due to the fact that they serve as favorable food sources to definite species of bacteria.

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#### PLATE 1

Fig. 1. Wheat in soil treated with pyridine. Three bottles on left are sterile; three bottles on right are inoculated.

Fig. 2. Wheat in soil untreated. Three tumblers on left contain soil from inoculated bottles; three tumblers on right contain soil from sterile bottles.

Fig. 3. Wheat in soil treated with pyridine. Three tumblers on left contain soil from inoculated bottles; three tumblers on right contain soil from sterile bottles. Compare with Fig. 1.

#### PLATE 2

Fig. 4. Wheat in soil treated with vanillin. Three tumblers on left contain soil from inoculated bottles; three tumblers on right contain soil from sterile bottles.

Fig. 5. Wheat in soil treated with coumarin. Three tumblers on left contain soil from inoculated bottles; three tumblers on right contain soil from sterile bottles.

Fig. 6. Wheat in soil treated with quinoline. Three tumblers on left contain soil from inoculated bottles; three tumblers on right contain soil from sterile bottles.





Fig. 1.



Fig. 2.

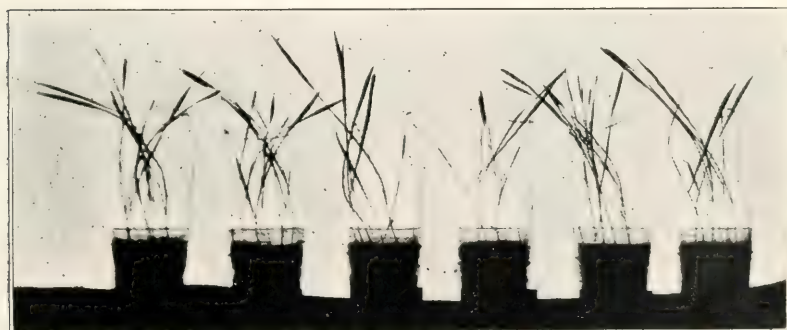


Fig. 3.



PLATE II.



Fig. 4.



Fig. 5.



Fig. 6.





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**The Nitrification of Pyridine, Quinoline,  
Guanidine Carbonate, etc., in Soils**

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**By**

**M. J. FUNCHESS**

**Associate Agronomist, Alabama Polytechnic Institute**

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# THE NITRIFICATION OF PYRIDINE, QUINOLINE, GUANIDINE CARBON- ATE, ETC., IN SOILS.<sup>a</sup>

BY

M. J. FUNCHESS,

Associate Agronomist, Alabama Polytechnic Institute.

## INTRODUCTION

In a previous publication it was shown that certain organic nitrogenous compounds, which had been described by others as being toxic to plants in water cultures, proved to be decidedly beneficial to crops in soil cultures (5)<sup>b</sup>. The yields obtained with both oats and corn were nearly as great with pyridine or quinoline as the source of nitrogen as when nitrate of soda was the source. From the plant growth obtained, it was very evident that these compounds were supplying nitrogen to the crops grown. Either these plants were using the compounds directly, or the compounds were being changed in the soil to some available form. Since most of the compounds studied in the work referred to above had already been proved to be toxic to higher plants in solution cultures, it was concluded that the substances were most likely decomposed to a simple form available to crop plants. If decomposition proceeded very far, in all probability, the nitrogen applied to a soil in the form of pyridine, or similar substances, would later be found as nitrates. It is the purpose of this paper to set forth the results from experiments to determine if such compounds are nitrified in soils.

## REVIEW OF LITERATURE

So far as the writer has been able to find from the literature available, the only instance where actual nitrification of the compounds used in this investigation has been observed is that recorded by Buddin. In studies on partial sterilization of soils by means of antiseptics Buddin (2) used pyridine, along with a number of other compounds. The action of pyridine was quite different from that of most other compounds

- (a) Published as a continuation of experiments reported in Alabama Experiment Station Bulletin No. 191.
- (b) Reference is made by number to "Literature cited" P. 81.

used, in that from its use there resulted an enormous increase in the number of bacteria present and a very great increase in the ammonia and nitrate content of the soil. The increased amounts of ammonia and nitrate were roughly proportional to the increased applications of pyridine, up to 7.9 gms. of pyridine per kilo. of soil.

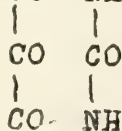
#### CHEMICALS USED.

The dihydroxystearic acid used in the work was made by Kahlbaum; the salicylic aldehyde was a synthetic product obtained from Eimer & Amend. All others were Merck's products.

According to results obtained in solution cultures, pyridine, quinoline, piperidine, guanidine carbonate, naphthylamine, and alloxan are toxic to wheat seedlings. Nucleic acid and asparagine are beneficial under the same conditions.

A brief description of the chemicals used, as taken from Bernthsen (1), Holleman (6), and Jones (7), follows:

Alloxan,  $\text{CO}-\text{NH}$  is a decomposition product of



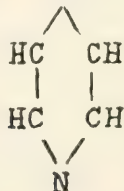
uric acid. It is readily soluble in water, and is of a strong basic nature.

Asparagine,  $\text{CO}_2\text{H} \cdot \text{CH}(\text{NH}_2) \cdot \text{CH}_2 \cdot \text{CO} \cdot \text{NH}_2$ , is an acid amide which is widely distributed in the vegetable kingdom.

Guanidine is a colorless, crystalline compound with strong basic properties. The carbonate,  $(\text{CN}_3\text{H}_3)_2 \cdot \text{H}_2\text{CO}_3$ , crystallizes in quadratic prisms. The base is readily hydrolysed, first to urea and ammonia, and finally to ammonia and  $\text{CO}_2$ .

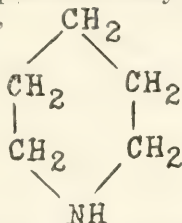
Naphthylamine,  $\text{C}_{10}\text{H}_7 \cdot \text{NH}_2$ , is a solid, basic compound, with an offensive odor.

Pyridine,  $\text{CH}$  is regarded as benzene with one CH



group placed by a N-atom. Pyridine acts as a base, forming salts with acids. It is a colorless liquid of great stability, being unattacked by boiling nitric acid, or chromic acid. Pyridine may be reduced to piperidine, and piperidine may be oxidized to pyridine.

Piperidine,  $\text{CH}_2$  is present in pepper

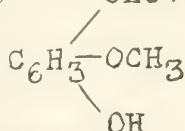


in combination as piperine. Piperidine is a colorless liquid with characteristic odor, and strong basic properties.

Quinoline,  $\text{C}_8\text{H}_7\text{N}$ , is a colorless liquid with peculiar odor. It yields salts with acids, acting like a tertiary base. It is considered to carry a benzene and a pyridine nucleus.

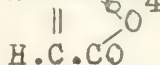
Nucleic acid is a complex substance. Yeast nucleic acid has been given the formula  $\text{C}_{40}\text{H}_{52}\text{N}_{15}\text{P}_3\text{O}_{32}$ . It yields on hydrolysis, guanosine,  $\text{C}_{10}\text{H}_{12}\text{N}_5\text{O}_5$ ; adenosine,  $\text{C}_{10}\text{H}_{12}\text{N}_5\text{O}_5$ ; cytidine,  $\text{C}_{10}\text{H}_{12}\text{N}_3\text{O}_5$ ; and uridine,  $\text{C}_9\text{H}_{12}\text{N}_2\text{O}_5$ .

Vanillin,  $\text{CHO}$ , is considered to be a hydroxal-



dehyde. It is the aromatic principle of vanilla, and is found in a number of different kinds of plants.

Cumarin has the following composition:  $\text{H} \cdot \text{C} \cdot \text{C}_6\text{H}_4$

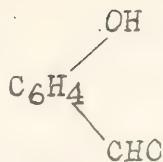


It is the aromatic principle of woodruff (*Asperula odorata*). It is soluble in hot water, ether and alcohol.

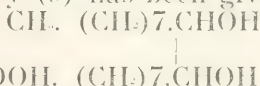
Pyrogallol is a trihydric phenol to which has been given the formula  $\text{C}_6\text{H}_3(\text{OH})_3$ . In alkaline solutions it is a strong reducing agent.

Salicylic aldehyde occurs in oil of spirea; its formula

is given as follows:



Dihydroxystearic acid as isolated from soils by Schreiner and Shorey (9) has been given the formula



and melting point of 99 degrees. The compound used in this work had a melting point of about 121 degrees, and since there is no known dihydroxystearic acid with this melting point, evidently the product used was impure, and of unknown identity.

## EXPERIMENTAL WORK

### METHODS

All of the experiments on nitrification of organic compounds herein reported were conducted in ordinary glass tumblers, using one hundred grams of air-dried soil in each tumbler. Before weighing out the soil, each lot to be used was thoroughly mixed so as to afford uniform samples. Unless otherwise stated, one gram of calcium carbonate, one tenth gram (or one tenth of a cubic centimeter in case of liquids) of the substance to be used was thoroughly mixed with the one hundred gram portions of soil in the tumblers. Sufficient distilled water was added to bring the soil to approximately optimum water content. The tumblers were then weighed, covered and set away in a dark closet in the laboratory. From time to time the tumblers were reweighed, and the loss made up with distilled water.

The phenoldisulphonic acid method was used for all nitrate determinations. Where large quantities of nitrates are present, the error involved in this method is probably great. But the data obtained are thought to be accurate enough to give reliable indications as to the nitrifications of the compounds studied. The contents of each tumbler were washed into a quart jar with 500 c.c. of a solution containing four c.c. of saturated potassium alum, one c.c. of formaldehyde, and four hundred and ninety-five c.c. of distilled water. The jars were then covered and vigorously shaken at

short intervals, after which they were allowed to stand until clear. Aliquots were then evaporated on the water bath, and the determinations made in the usual way. Except in table II the data given represent the average of duplicate determinations.

### NITRIFICATION OF PYRIDINE, QUINOLINE, GUANIDINE CARBONATE, ETC.

To determine whether the compounds used in this work were nitrified in the soil to an appreciable extent, and to determine the effect of lime on the nitrification, the methods described above were used. The period of incubation varied with the soil used, from three and one half to five months. Three different soils were used. Soil No. 1 was obtained from a plot on the Experiment Station Farm which had received annually a moderate application of ammonium sulphate, and is quite acid. The experiment on this soil ran from June 15 to September 21, 1916. Soil No. 2 was obtained from what is known as the "Cullers Rotation Field," about one mile south of Auburn. This soil, classed as Norfolk sandy loam by the Bureau of Soils, is slightly acid. The test ran from June 16 to September 16, 1916. Soil No. 3 came from what is known as the "square acre" on the Experiment Station Farm. It is moderately acid. This experiment ran from Feb. 18 to June 21, 1915. The treatments given, and the amounts of nitrates found in the soils, in both limed and unlimed conditions, are shown in table I.

TABLE I. *Nitrification of Dried Blood, Pyridine, Quinoline, Etc. Nitrates Expressed as p. p. m. of Dry Soil.*

| Treatment                 | Soil No. 1 |           | Soil No. 2 |           | Soil No. 3 |           |
|---------------------------|------------|-----------|------------|-----------|------------|-----------|
|                           |            | With lime |            | With lime |            | With lime |
| Dry checks .....          | None       |           | 1.3        |           | 1.3        |           |
| Dist. water .....         | 56.0       | 145.0     | 58.7       | 177.5     | 58.3       | 145.0     |
| Dried blood .....         | 145.0      | 480.0     | 235.0      | 390.0     | 260.0      | 460.0     |
| Pyridine .....            | 192.5      | 240.0     | 185.0      | 245.0     | 145.0      | 185.0     |
| Quinoline .....           | 152.5      | 20.0      | 55.0       | Trace     | 215.0      | 180.0     |
| Piperidine .....          | 155.0      | 290.0     | 165.0      | 325.0     | 268.0      | 400.0     |
| Guanidine carbonate ..... | 200.0      | 2.0       |            |           | 140.0      | 6.8       |
| Nucleic acid .....        |            |           |            |           | 245.0      | 530.0     |
| Alloxan .....             |            |           |            |           | 275.0      | 540.0     |
| Asparagine .....          |            |           |            |           | 275.0      | 540.0     |
| Nanthylamine .....        |            |           |            |           | 1.6        | 2.2       |



A study of the data presented in table I. shows clearly that, of all the compounds used, and in each of the three different soils, naphthylamine and quinoline in soil No. 2, were the only substances which were not nitrified. Of the three soils used, No. 1 is most acid, and No.2 is least acid. Quinoline was apparently not nitrified in the least acid soil, but in the soils which were moderately or strongly acid, this basic compound was nitrified to quite an appreciable degree. Further, the addition of lime to the least acid soil inhibited nitrification, but only reduced the process in the more acid soil. In both limed and unlimed conditions, pyridine was nitrified in each of the soils used. But the effect of lime on the nitrification of this basic compound is not nearly so great as in the case of dried blood or the other non-basic materials. The fact that so stable a compound as pyridine, which is unaffected by boiling nitric acid, or chromic acid, is nitrified in these soils, illustrates in a very definite way the enormously destructive chemical and biochemical action that may take place in soils. Piperidine was nitrified in each of the soils, the addition of lime increasing the amount of nitrification in each case; this too, in spite of the fact that the compound is of a strong basic character. In the unlimed acid soils, guanidine carbonate, another basic compound, was readily nitrified; in the limed series, however, nitrification was inhibited. Nucleic acid, alloxan, asparagine and naphthylamine were used in but one soil. Of these, only naphthylamine was not nitrified. As in the case of dried blood, the decomposition of these non-basic substances was greatly increased by the addition of lime.

#### THE EFFECTS OF VARYING AMOUNTS OF NITROGENOUS COMPOUNDS ON NITRIFICATION

The effect of concentration of the nitrogenous compounds on nitrification was also studied. The soil used in this case was a poor, sandy soil which had been left undisturbed in the green house for several months, and had accumulated quite a large amount of nitrates. Each tumbler contained ninety-seven grams of this poor sand, one gram of fertile soil and two grams of lime. The period of incubation lasted from July 11th to September 8th, 1915.

TABLE II.—*Effect of Varying Amounts of Nitrogenous Compounds on the Rate of Nitrification.*

| Treatment       | NO <sub>3</sub> in p. p. m. of air dry soil from |          |           |          |
|-----------------|--------------------------------------------------|----------|-----------|----------|
|                 | 0                                                | 0.5 gram | 0.25 gram | 0.1 gram |
| Dry checks      | 137                                              |          |           |          |
| Distilled water | 231                                              |          |           |          |
| Dried blood     |                                                  | 1225     | 850       | 525      |
| Asparagine      |                                                  | 175      | 550       | 486      |
| Naphthylamine   |                                                  | 187      | lost      | 175      |
| Alloxan         |                                                  | 187      | 200       | 525      |
| Nucleic acid    |                                                  | 360      | 237       | 625      |
| Quinoline       |                                                  | 175      | 200       | 200      |
| Pyridine        |                                                  | 200      | 212       | 225      |

With the exception of dried blood and naphthylamine, more nitrates were formed from ten tenth gram treatments than from the half gram treatments. The heavier applications of asparagine, alloxan, and nucleic acid exerted a decided inhibitory effect on nitrification. Compared with the distilled water check, pyridine, and quinoline slightly retarded nitrification. It is probable that this experiment was of too short duration for the last named compounds to be decomposed in the very poor soil used. Or, the two grams of lime per tumbler may have retarded their nitrification, since in other experiments lime has been found to be inhibitory to the decomposition of quinoline, and of but little benefit to the decomposition of pyridine.

#### THE EFFECT OF PARTIAL STERILIZATION OF SOIL ON NITRIFICATION OF PYRIDINE, QUINOLINE, ETC.

In view of the fact that various investigators have reported that treatment of the soil with carbon disulphide destroys the nitrifying organism, it was thought of interest to study the effect of "partial sterilization" on the nitrification of these compounds. Carbon disulphide was added to a number of tumblers in sufficient quantity to moisten about one half of the 100 gram samples of soil used. After standing covered for about 24 hours, the soil in the tumblers was exposed to the air and allowed to stand for about ten days so as to rid the soil of the antiseptic. One series received no lime, a second series was limed, and a third series was limed and reinoculated with an infusion from the untreated soil. During the time that this experiment was in progress, no special attempt was made to avoid contamination of the soil treated with the antiseptic. However, distilled water was used throughout, and

each tumbler was kept covered in a dark closet. The soil used came from a plot on the Experiment Station Farm which was very acid, due largely to the application of sulphate of ammonia in the field treatment. The test ran from June 15 to September 17, 1916.

TABLE III.—*The Effect of Partial Sterilization of Soil on the Nitrification of Pyridine, Quinoline, Etc.*

| Treatment                           | NO <sub>3</sub> in p. p. m. of soil treated with |       |                       |
|-------------------------------------|--------------------------------------------------|-------|-----------------------|
|                                     | 0                                                | Lime  | Reinoculated and lime |
| Dry checks                          | 0                                                | ----- | -----                 |
| Distilled water                     | 56                                               | 145   | -----                 |
| Distilled water and CS <sub>2</sub> | trace                                            | 112   | -----                 |
| Dried blood                         | 145                                              | 480   | -----                 |
| Dried blood and CS <sub>2</sub>     | trace                                            | 233   | 380                   |
| Pyridine                            | 192                                              | 240   | -----                 |
| Pyridine and CS <sub>2</sub>        | 58                                               | 305   | 385                   |
| Quinoline                           | 152                                              | 20    | -----                 |
| Quinoline and CS <sub>2</sub>       | trace                                            | trace | 21                    |
| Piperidine                          | 155                                              | 290   | -----                 |
| Piperidine and CS <sub>2</sub>      | 19                                               | 381   | 427*                  |

\* In recording the data, fractions of a part per million were frequently omitted if the nitrate content was great.

The results which are tabulated in table III. show that nitrifying organisms gained entrance to the tumblers, or that the carbon disulphide treatment failed to destroy all of the nitrifying bacteria. From unpublished data obtained by the writer, he believes that the presence of nitrifying organisms in the soil treated with carbon disulphide was not due to contamination, but to the fact that the organisms were not killed by the antiseptic.

Carbon disulphide inhibited nitrification in the untreated soil and in the soil treated with dried blood or quinoline, and seriously reduced the process in soil treated with pyridine or piperidine. In the presence of lime, the antiseptic reduced nitrification in the untreated soil and in the soil treated with dried blood or with quinoline. On the other hand, with carbon disulphide and lime, more nitrates were formed from pyridine and from piperidine than were obtained from these compounds alone. The effect of reinoculation was to increase in all cases the amounts of nitrates recovered.

# THE EFFECT OF NON-NITROGENOUS SUBSTANCES TOXIC TO PLANTS IN WATER CULTURES, ON THE NITRIFICATION OF DRIED BLOOD, PYRIDINE, ETC.

Davidson (3) has shown that the addition of vanillin or cumarin to soil which had been treated with lime, sodium nitrate, or potassium chloride, decreased nitrification; while, in the presence of disodium phosphate, there was greater nitrification in the vanillin and cumarin treated soils than in the controls. He suggests that the action of vanillin and cumarin on nitrification may be analogous to the behavior of soluble organic matter in general.

The writer studied the effect of vanillin, cumarin, pyrogallol and salicylic aldehyde on the nitrification of dried blood, pyridine, quinoline, piperidine and guanidine carbonate, in both limed and unlimed conditions. The methods employed were the same as indicated above.

Two soils were used, one of which, a Norfolk sandy loam, was obtained from the Cullers rotation plots; and the other was obtained from the very acid plot on the Experiment Station Farm.

In the slightly acid Norfolk sandy loam soil, as can be seen from table IV, dried blood, pyridine and piperidine produced notable increases in the nitrate content of the soil. From quinoline, however, not quite as much nitrates were produced as from the soil treated with water only. The addition of lime to quinoline inhibited nitrification; but, with dried blood, pyridine, and piperidine, lime increased nitrification.

Pyrogallol alone retarded nitrification of dried blood and pyridine, but slightly increased nitrate formation from quinoline and piperidine. Comparing the pyrogallol-lime series with the nothing-lime series, less nitrates were obtained in the presence of pyrogallol than where it was absent. It is apparent, however, that the inhibitory action of pyrogallol is quite largely overcome by lime.

Vanillin alone practically inhibited nitrification of pyridine and quinoline, seriously reduced the process with dried blood, but had very little effect on the nitrification of piperidine. Lime reduced to a marked degree the toxic action of vanillin toward the nitrification of pyridine and dried blood. In no instance was the nitrate content of the vanillin-lime series as high



as in the nothing-lime series, showing that lime failed to completely overcome the bad effect of the vanillin.

TABLE IV.—*The Effect of Non-Nitrogenous Substances on the Nitrification of Dried Blood, Pyridine, Etc., in Norfolk Sandy Loam Soil. Nitrates Expressed as p. p. m. of Dry Soil.*

| Nitrogenous compounds added | Nothing |           | Pyrogallol |           | Vanillin |           | Cumarin |           | Salicylic aldehyde |           |
|-----------------------------|---------|-----------|------------|-----------|----------|-----------|---------|-----------|--------------------|-----------|
|                             |         | With lime |            | With lime |          | With lime |         | With lime |                    | With lime |
| Dry check                   | 1.3     |           |            |           |          |           |         |           |                    |           |
| Dist. water                 | 58.7    | 177.5     |            |           |          |           |         |           |                    |           |
| Dried blood                 | 235.0   | 390.0     | 101.0      | 300.0     | 122.0    | 275.0     | 210.0   | 352.0     | trace              | trace     |
| Pyridine                    | 185.0   | 245.0     | 150.0      | 197.0     | 4.8      | 200.0     | 112.0   | 56.0      | trace              | trace     |
| Quinoline                   | 55.0    | trace     | 67.0       | trace     | trace    | trace     | trace   | trace     | trace              | trace     |
| Piperidine                  | 165.0   | 325.0     | 205.0      | 260.0     | 160.0    | 285.0     | 152.0   | 297.0     | trace              | trace     |

Nitrification of dried blood and piperidine was but slightly reduced by cumarin alone. However, this compound materially reduced nitrification of pyridine, and inhibited the process with quinoline. Lime increased the toxicity of cumarin to nitrification of pyridine, but greatly reduced it to the decomposition of dried blood and piperidine. No nitrates were formed from quinoline with or without lime. In those instances where lime reduced toxicity of cumarin, comparison with the nothing-lime series shows that the toxicity was not entirely overcome.

Salicylic aldehyde completely inhibited nitrification in all cases.

In all cases, in the very acid soil, the data for which are given in table V. the various nitrogenous compounds gave rise to more nitrates than were obtained from the distilled water check. Attention is called to the fact that in this very acid soil, quinoline is nitrified, while in the slightly acid Norfolk sandy loam, it is not nitrified. Lime increased nitrification in each case except in the quinoline and guanidine carbonate treated soil, in which instances lime markedly reduced nitrification. From the data given, it is evident that lime reduces or completely inhibits nitrification of quinoline. On the other hand, this basic compound is apparently most readily nitrified in the soil having the highest acidity.



TABLE V.—*The Effect of Non-Nitrogenous Substances on the Nitrification of Dried Blood, Pyridine, Etc., in Acid Soil from the Experiment Station Farm. Nitrates Expressed as p. p. m. of Dry Soil.*

| Nitrogenous compounds added | Nothing |           | Pyrogallol |           | Vanillin |           | Cumarin |           | Salicylic aldehyde |           |
|-----------------------------|---------|-----------|------------|-----------|----------|-----------|---------|-----------|--------------------|-----------|
|                             |         | With lime |            | With lime |          | With lime |         | With lime |                    | With lime |
| Dry check -----             | 1.3     |           |            |           |          |           |         |           |                    |           |
| Dist. water -----           | 58.7    | 177.5     |            |           |          |           |         |           |                    |           |
| Dried blood -----           | 145.0   | 480.0     | 47.0       | 180.0     | 92.0     | 305.0     | 97.0    | 365.0     | trace              | trace     |
| Pyridine -----              | 192.0   | 240.0     | 107.0      | 275.0     | 130.0    | 345.0     | 195.0   | 240.0     | trace              | trace     |
| Quinoline -----             | 152.0   | 20.0      | 90.0       | trace     | trace    | trace     | 152.0   | trace     | trace              | trace     |
| Piperidine -----            | 155.0   | 290.0     | 125.0      | 360.0     | 130.0    | 435.0     | 132.0   | 245.0     | 22.3               | 38.0      |
| Guanidine carbonate -----   | 200.0   | 2.0       |            |           |          |           |         |           |                    |           |

Pyrogallol alone materially retarded the nitrification of dried blood, pyridine and quinoline, and slightly retarded nitrification of piperidine. Compared with the nothing-lime series, pyrogallol with lime increased the nitrification of dried blood, pyridine and piperidine, but inhibited the process with quinoline.

In the presence of vanillin alone, each of the compounds was nitrified less than when vanillin was absent. On the other hand, two of the compounds were nitrified more with vanillin and lime than with lime alone. Just why the combined action of pyrogallol and lime, or vanillin and lime, should favor nitrification more than does the lime alone, is not clear.

By the addition of cumarin, nitrification of dried blood and piperidine was reduced considerably below that found in the nothing series. Pyridine and quinoline, however, were nitrified as well with cumarin present as without cumarin. In the presence of lime, the inhibitory effect of cumarin on the nitrification of dried blood and piperidine was materially reduced; while there was no effect from lime in the pyridine-cumarin treated soil. Lime in addition to cumarin completely inhibited nitrification of quinoline.

Salicylic aldehyde inhibited nitrification in all instances except with piperidine, in the presence of which compound a small amount of nitrate was found in the unlimed series. Salicylic aldehyde persists in soils longer, as indicated by smell, than any other compound used in the experiments here reported.

THE EFFECT OF COMBINATIONS OF NON-NITROGENOUS COMPOUNDS TOXIC TO PLANTS IN SOLUTION CULTURES, ON THE NITRIFICATION OF DRIED BLOOD, PYRIDINE, ETC.

A study of the effect of one, or the combined effect of two, or three, non-nitrogenous compounds on nitrification was made in 1915, using Norfolk sandy loam soil similar to that used in other tests reported on the previous pages. The data obtained are presented in table VI.

TABLE VI.—*The Effect of Combinations of Non-Nitrogenous Compounds on the Nitrification of Dried Blood, Pyridine, Etc. Nitrates Expressed as p. p. m. of Dry Soil.*

| Nitrogenous compounds added | Nothing |           | Vanillin |           | Vanillin and cumarin |           | Vanillin, cumarin and dihydroxystearic acid |           |
|-----------------------------|---------|-----------|----------|-----------|----------------------|-----------|---------------------------------------------|-----------|
|                             |         | With lime |          | With lime |                      | With lime |                                             | With lime |
| Dist. water                 | 135.0   |           |          |           |                      |           |                                             |           |
| Dried blood                 | 290.0   | 540.0     | 180.0    | 490.0     | trace                | 71.0      | 9.0                                         | 100.0     |
| Pyridine                    | 215     |           | 85.0     |           | trace                |           | trace                                       | 55.0      |
| Quinoline                   | 185.0   |           | 7.0      |           | trace                |           | trace                                       | 37.0      |
| Piperidine                  | 265.0   |           | 280.0    |           | trace                |           | trace                                       | 112.0     |
| Guanidine                   |         |           |          |           |                      |           |                                             |           |
| Carbonate                   | 445.0   |           | 19.0     |           | trace                |           | trace                                       | trace     |

In the soil otherwise untreated each of the compounds was nitrified, the highest nitrate content being found in soil treated with guanidine carbonate, and the lowest, in soil treated with quinoline.

By the addition of vanillin, nitrification of all compounds was seriously reduced, with the exception of piperidine, from which more nitrates were formed with vanillin than without it.

The combined action of vanillin and cumarin was to inhibit completely the nitrification of all compounds. Dried blood was slightly nitrified in the presence of these two non-nitrogenous compounds, where lime was added; unfortunately, lime was not used in connection with the other nitrogenous substances.

In the presence of vanillin, cumarin, and dihydroxystearic acid, nitrification was inhibited in all cases except in the soil treated with dried blood, in which there was found a very small amount of nitrates. In the limed series, however, a varying quantity of ni-

trates was recovered from each treatment except guanidine carbonate; the amount recovered from the soil treated with dried blood and piperidine averaged 100 and 112 parts per million of soil, respectively. The great corrective effect that lime may exert in soil is very strikingly shown by the results set forth above.

INFLUENCE OF LIME, CARBON BLACK, AND PYROGALLOL ON  
NITRIFICATION OF DRIED BLOOD IN PRESENCE OF VANILLIN  
CUMARIN, AND DIHYDROXYSTEARIC ACID.

It has been shown that the toxicity of soil extracts may be partially or even completely removed by the use of such compounds as carbon black, pyrogallol or lime. It was thought probable, therefore, that these compounds might have a beneficial effect on nitrification in soil to which toxic compounds were added. To test this, a number of tumblers were prepared in the usual way, and treated as shown in table VII.

From each of the comparisons which may be made with this data, it is seen that pyrogallol exhibited an inhibitory effect on nitrification.

Lime had a beneficial effect on nitrification under each of the conditions in which it was used. This result was to be expected from the numerous instances given in which the action of lime was shown to be helpful.

TABLE VII.—*The Effect of Lime, Pyrogallol and Carbon Black on Nitrification of Dried Blood in Presence of Vanillin, Cumarin, and Dihydroxystearic Acid. Nitrates Expressed as p. p.m. of Dry Soil.*

| Corrective materials added        | Dried blood | Dried blood and vanillin | Dried blood, vanillin, cumarin | Dried blood vanillin, cumarin, Dihydroxystearic acid |
|-----------------------------------|-------------|--------------------------|--------------------------------|------------------------------------------------------|
| None                              | 290.0       | 180.0                    | trace                          | 9.0                                                  |
| Lime                              | 540.0       | 490.0                    | 71.0                           | 100.0                                                |
| Carbon black                      |             | 190.0                    | 140.0                          | 105.0                                                |
| Pyrogallol                        |             | 55.0                     | trace                          | trace                                                |
| Lime and carbon black             |             |                          |                                | 370.0                                                |
| Carbon black and pyrogallol       |             |                          |                                | 47.0                                                 |
| Lime, carbon black and pyrogallol |             |                          |                                | 182.0                                                |

The results obtained with carbon black are very interesting. In no case was there an apparent harmful effect, and in several instances there was marked benefit to the process of nitrate formation. Carbon black materially reduced the toxic effect of vanillin and cumarin; and of vanillin, cumarin and dihydroxystearic acid. Indeed, the combined effect of lime and carbon black was to overcome quite largely the toxicity of cumarin, vanillin, and dihydroxystearic acid combined.

### DISCUSSION

The evidence here brought together would seem to show that, under the conditions of these experiments, even extremely stable nitrogenous compounds may be decomposed in soils. The recent results obtained by Robbins (8) indicate that such decomposition may be due, wholly or in part, to the action of soil organisms. In view of such decomposition, it is very doubtful if these or similar substances would accumulate in soils, under similar conditions, in sufficient quantities to become harmful to growing plants.

A very interesting point developing from this work is the indication that *certain basic compounds, as quinoline or guanidine carbonate, are nitrified best in acid soils, and that liming of acid soils prevents the decomposition of such substances.* Indeed, the addition of lime may not only prevent the nitrification of quinoline and guanidine carbonate, but the combined action of lime and these basic substances may also suppress the nitrification of organic compounds normally occurring in soils. Evidence to support this view may be found in tables I., IV. and V. A possible explanation may be that the organisms which have the ability to decompose these compounds function only in acid soils. Or, it may be that the first stages of decomposition are effected by organisms other than bacteria, and that these are not active in the limed soils. Further, the basic compounds may form salts in the acid soils, which salts are more readily nitrified than the original compounds. If this last view be correct, the suppression of nitrification in the limed soils may be due to the prevention by lime of salt formation between quinoline and guanidine carbonate, and acid bodies existing in soils. Not all of the basic compounds, however, were affected alike by liming, since *pyridine was decomposed in the limed soils, and the decompo-*



sition of piperidine was considerably increased by liming. From the foregoing it might be suggested that a different organism, or group of organisms, should be involved in the decomposition of such compounds.

Another interesting point which deserves mention is the non-toxic action of vanillin toward the decomposition of piperidine. In vanillin treated soils nitrification of dried blood and pyridine was seriously reduced, and of quinoline, practically inhibited. But the decomposition of piperidine was about as great in the presence of vanillin as in the untreated soils. There are several possible explanations of these differences. The decomposition of piperidine may be caused by an organism, or group of organisms, which are unaffected by vanillin; while the nitrification of quinoline, etc., may be due to an organism or group of organisms to which vanillin is toxic. Again, vanillin may be toxic to the nitrification of piperidine, quinoline and similar substances. But in presence of piperidine, certain organisms destroy the vanillin, thereby permitting piperidine decomposition to proceed; while in the presence of quinoline the action of the vanillin destroying organism or organisms is inhibited. In other words, there might be a mutual inhibition of the organisms requisite to quinoline and vanillin decomposition.

It is rather generally accepted that liming an acid soil increases nitrification, and this view seems to be correct for a large number of compounds. However, quinoline and guanidine carbonate are two exceptions to be noted among the compounds used in this work. And it is conceivable that other basic nitrogenous compounds may be nitrified best in acid soils. Again, the fact that a substance inhibits the nitrification of one compound is not proof that the compound inhibits nitrification in general. For example, vanillin reduces or even inhibits the nitrification of quinoline, while the nitrification of piperidine seems to be but little affected by the addition of vanillin. Likewise, coumarin may exert a decided inhibitory effect on the nitrification of one compound and but little on another. Further, the inhibitory action of a compound toward nitrification may be quite different in different soils. In view of the results here given, a general rule in regard to nitrification would appear to be impossible.

In most instances lime greatly reduced the toxicity of pyrogallol, vanillin and coumarin, toward nitrifica-



tion. The beneficial results obtained with lime may be due to the neutralization of soil acidity, thereby increasing bacterial activity, or the lime may react, directly or indirectly, with these compounds, the resultant products being less injurious than the original.

In several instances, greater nitrification was found in the lime-pyrogallol series and the lime-vanillin series than in the lime series alone. It may be possible to explain these rather peculiar results, in the light of recent work by Doryland and by Robbins. The results obtained by Doryland (4) tend to show that while a large amount of energy-producing material may give rise to such large numbers of bacteria that the ammonia produced from a nitrifiable substance may be entirely consumed by the bacteria, a small amount of energy-producing material may actually increase ammonia accumulation. The explanation offered is that the small amount of energy-producing material induces large numbers of bacteria in the medium. When this small amount of energy-producing material is exhausted the nitrogenous compounds remaining are attacked as a source of energy, causing rapid ammonification and ammonia accumulation. Robbins (8) has shown that the addition of coumarin or vanillin to soil enormously increases the number of bacteria present. He has shown, further, that certain bacteria are able to use these compounds as sources of energy. It may be possible, therefore, to explain the increased nitrification in the presence of vanillin as being due to the increased numbers of bacteria induced by the small amounts of vanillin added. The vanillin in this case producing effects similar to those found by Doryland, where small amounts of energy-producing material like dextrose caused increased ammonia accumulation.

#### SUMMARY

(1) With the exception of naphthylamine, each of the compounds used in this study was nitrified in soil.

(2) At the concentration used, naphthylamine inhibited nitrification in both limed and unlimed soil.

(3) Quinoline was nitrified most readily in soil having the highest lime requirement. Lime retarded or even inhibited nitrification of quinoline.

(4) Lime practically inhibited nitrification of guanidine carbonate. Nitrification of dried blood, piperidine, nucleic acid, alloxan, and asparagine, was greatly increased by lime.

(5) Heavy applications of certain nitrogenous compounds may retard nitrification.

(6) Liming a soil which had been partially sterilized with carbon disulphide greatly increased its power of nitrification. A still further increase was obtained by reinoculation of the soil after partial sterilization.

(7) Vanillin proved to be non-toxic toward nitrification of piperidine, moderately toxic toward nitrification of dried blood and pyridine and inhibitory toward nitrification of quinoline.

(8) Lime counteracted the toxicity of vanillin to a very large degree.

(9) The effect of coumarin on nitrification was quite variable. In some instances it exerted an inhibitory effect; in others, none.

(10) In most cases where coumarin exerted an inhibitory effect, lime greatly reduced the amount of inhibition.

(11) Pyrogallol retarded nitrification of all compounds, except quinoline and piperidine, in one soil.

(12) Lime reduced the injurious effect of pyrogallol in all cases, except in the quinoline treated soil.

(13) Salicylic aldehyde completely inhibited nitrification of all compounds, except piperidine, in one soil.

(14) Carbon black apparently overcomes a part of the bad effect of certain non-nitrogenous compounds on the process of nitrification.

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**Agricultural Experiment Station**

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**AUBURN**

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**Harvesting and Storing Sweet Potatoes**  
(POPULAR EDITION)

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By  
**J. C. C. PRICE**

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# HARVESTING AND STORING SWEET POTATOES

By

J. C. C. PRICE, Associate Horticulturist

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## INTRODUCTION

Storage has proved to be the most serious problem of sweet potato growing. Storage in banks, pits and trenches is not always satisfactory, because sweet potatoes require a warm, dry, rapidly changing atmosphere during the curing period, and a uniform temperature and humidity after curing. Such conditions are found only in a storage house. When the pit, bank or trench methods are used from 10 to 100 per cent rot and those that keep are not of as good quality as are the cured potatoes. Even if potatoes would keep as well in trenches or banks, these methods are not economical, because too much labor is required each year to make and use them. It costs ten to twelve cents per bushel to bank sweet potatoes, unbank and clean them for market. Potatoes cannot be removed conveniently from banks in rainy or cold weather without injuring the potatoes or causing decay; but they can be conveniently marketed from the storage house at any time without regard to weather conditions and without damaging the rest of the crop.

Uniformity of temperature and humidity are two of the most important factors in the storage of any perishable crop. The ability to control humidity and temperature is the most important factor in curing a perishable crop. It is also a well established principle of storage that a rapid rise or fall of either temperature or humidity is not desirable.

## MAKING THE EXPERIMENTAL STORAGE ROOM

In order to make a thorough test of house curing and storage of sweet potatoes under Alabama conditions, one large room of a negro cabin (Fig. 3) standing on the Experiment Station grounds, was remodeled during the fall of 1914 as follows:

The cracks in the rough board walls were covered on the outside with one-half by three inch strips. The walls inside were covered with building paper. The rough board floor was covered with building paper



and a tongue and grooved floor was laid over this and at right angles to the boards of the first floor. Care was taken to join the floor carefully to the outer walls so as to keep out rodents or air. Two by four inch scantlings were set vertically two feet apart around the walls and a layer of paper tacked upon these. This provided a four inch dead air space between the two by fours from floor to ceiling, thus giving excellent protection from sudden changes of temperature.

The walls were then ceiled with the same material as that used for the floor. The rough board ceiling was simply covered with building paper during the first season, but was also ceiled at the beginning of the second year. The effect of this change is clearly shown by the much more constant temperatures maintained the second year.

The windows on the north and east sides of the house were replaced by hinged doors, composed of two layers of matched boards with building paper between, so as to provide ventilation during the curing period. The door at the south-east corner of the house was remodeled by covering with paper and an extra layer of boards.

An eight by ten inch ventilator opening was cut in the floor at each of the four corners of the room as a part of the ventilating system. These openings could be closed at will by means of sliding covers. A flue, made by nailing four six inch boards together, extended through the ceiling in the center of the room and out through the roof. The top of this flue was roofed to keep out rain and the ceiling opening could be closed at will by a sliding board.

### BUILDING THE BINS

The bins (see fig. 4) were constructed as follows: Two by fours were used for the uprights, or posts, which were toenailed to the floor and ceiling. One inch by three inch strips were nailed to the corner posts for the sides and backs, leaving a one inch space between the strips. The backs of the bins were made first and then set in place, since there is not room in the narrow space to work. Edging strips, (which may be had at the saw mill at a cost not exceeding fifty cents for a two-horse wagon load) were used for constructing the bins and were entirely satisfactory. The false bottoms were made by nailing stout edging strips on

three pieces of two by fours cut two inches shorter than the width of each bin, placing the two by fours on edge, one near each end and one near the middle. The false bottoms were made detached so they could be removed easily when the house was to be cleaned. Both sides of the scantling between the bins were slatted so as to leave an air space between the potatoes in adjacent bins. When built as described above there was a four inch air space all around each bin. The bins varied in width, the general size being three feet wide, seven feet long and seven feet high.

An ordinary sheet iron, wood stove was installed in the center of the room and connected with the chimney at one end of the room. A coal stove of the hot blast type was used the third year. It gave a more satisfactory heat than the wood stove.

### COST OF REMODELING THE ROOM

The total cost of remodeling the room, which had a capacity of about six hundred bushels, including all material, labor and stove was less than fifty dollars. It will serve our purpose indefinitely.

### HARVESTING THE CROP

In order to make the experiment of practicable value, the principles of correct harvesting were carefully followed. The potatoes were allowed to mature in order to produce a maximum yield and develop high quality. An immature potato is difficult to cure. If a potato is broken and the surface turns white and dries within a few minutes, it is mature and ready to dig. Frozen potatoes or potatoes from frozen vines are dangerous for human food and will not keep in storage. Therefore, our crop was harvested as soon as mature and before there was serious danger of frost. (See chart for date of first killing frost in various parts of the State.) Bruised, cut and broken potatoes are difficult to cure and store. Hence care was exercised in the methods of removing the vines as well as in digging and hauling the potatoes. A six foot McCormick hay rake was used for removing the vines, (see Fig. 9) taking two rows at a time. This cleaned the vines off the rows and left them in heaps, thus facilitating their removal from the field. The rake rarely, if ever, injured a potato, as is so often done by a cultivator or a rolling coulter. The digging implement (Fig. 5) was

easily run deep enough to prevent cutting and bruising the potatoes. The pronged mould board of this digger separated the potatoes from the soil, thus preventing unnecessary handling. Neither the common "scooter" or Dixie turning plow is satisfactory, as they bruise and cut too many of the potatoes found deep in the ground. In dry, hard ground, digging was made easier by barring off one side and then running the digger under the row.

Baskets lined with old sacks were used in gathering as they prevented bruising and breaking the skin. Hay was placed in the wagon bed in lieu of springs and the potatoes were hauled to the storage house in the baskets to reduce handling to a minimum.

### TIME OF HARVESTING

Table I. shows the average date of the first killing frost for Alabama for four years, prior to the date of the beginning of these experiments. The date of the first killing frost for 1914 at Auburn was November 20th; for 1915, November 16th; and for 1916, November 16th. This shows conclusively that it is not safe to wait later than November 1st to begin harvesting a large crop.

TABLE I.

|                     |               |
|---------------------|---------------|
| Huntsville, Alabama | October 25th  |
| Birmingham, Alabama | November 1st  |
| Montgomery, Alabama | November 10th |
| Mobile, Alabama     | November 20th |

### FILLING THE BINS

A fire was started in the storage house and doors, windows, and ventilators opened the day before digging was begun, to raise the temperature and expel excess moisture. The potatoes were hauled in each day as soon as dry. No sorting or grading was done in the field. (But should be done for best results.) The workmen filled the back of the bins first and all to the same depth when possible rather than filling one bin at a time, since the potatoes would cure slowest at the bottom where the cold moist air would naturally settle. A slatted partition was put across the middle of the long bins, thus permitting the back of the bins to be filled without walking over the potatoes in front. The partition was made in sections and set in against the cleats as the bins were filled. The partition across the middle of the bins and the gates

at the ends had one inch space (see Fig. 4) between the slats to give good ventilation.

### THE CURING PERIOD

In storage house, the curing required was from ten days to two weeks, depending upon weather conditions. When the weather was cool or rainy, or both, curing was retarded as the air was already saturated with moisture. It was harder to keep the temperature up to the desired degree on cold days. Moisture is given off from the potatoes much more slowly when the temperature is low and the air is more nearly saturated with moisture.

Some varieties of potatoes cured more easily than did others. The wet, juicy or sugary varieties cured much more slowly than the dry varieties. It required from three to five days longer to cure the Dooley Yam than the Triumph and Nancy Hall. The curing in these experiments was timed for Triumph. Good results were secured, however, with Nancy Hall and Porto Rico. Many other varieties were stored in the same room but the proper curing period for each variety could not be ascertained. There was consequently a greater loss from dry or soft rot among the other varieties. The cultural and other experiments seem to show that Triumph, Nancy Hall and Porto Rico are the three most valuable varieties, so no record of other varieties is given.

The curing process was considered complete when the tubers felt dry and spongy to the touch and the cut or skinned surface had formed a dry, white callous.

### CURING TEMPERATURE

The air inside the storing house was kept warmer than the air outside through the curing period. If it was impossible to keep the temperature up to 80 to 85 F. during the curing period, the ventilators, door and window were kept open so as to expel the moisture and prevent it being deposited on the walls. On cool nights the house was closed.

As the storage house was not ready until after the potatoes had been dug in 1914, they were stored in the greenhouse laboratory until the house was sufficiently completed for them to be removed into it. Many of the cut and bruised potatoes had begun to decay due to this delay. The potatoes showing signs of rot were



thrown out, but sound potatoes that came in contact with those already decayed were infected with spores. Hence, rotting continued to a degree in the storage house.

This, with the uncompleted overhead ceiling, largely accounts for the higher loss record for the first year. During that season unfavorable weather conditions prevailed after the digging season and the loss among potatoes stored in banks was complete in many cases through the State.

### STORAGE TEMPERATURE

At the end of the curing period the house was closed tight. The temperature inside the house responded slowly to the outside temperature and was usually between fifty and sixty Fahrenheit at Auburn. During cold weather the temperature was not allowed to fall below forty degrees Fahrenheit, a fire being built and maintained as long as needed. At such times care was taken not to raise the temperature above sixty-five degrees Fahrenheit.

### COMMENTS ON STORAGE RESULTS

The potatoes stored at Auburn in banks as a part of this experiment, were taken immediately from the field and banked as practiced by farmers near Auburn. Therefore, for that reason in 1914 the banked potatoes had an advantage in prompt handling over the house-stored potatoes. The records for 1915-1916 and 1916-1917 show a more accurate comparison between house and bank storage because the house once completed was ready each year and potatoes were stored as soon as dug, and cured promptly.

In addition to the work done at Auburn, Table II, part 1, arrangements were made with three farmers to cooperate on storing sweet potatoes in banks and in houses. The results of these storage tests are also shown in this table.

Note the results of the experiment in cooperation with Mrs. Bellamy, Table II, Part 2. In 1915-16 the percent of loss in banks was a little more than double that in the house, while in 1916-17 the loss in banks was nearly eighteen times that in the house. The room used by Mrs. Bellamy was one room of the servants' cottage, without floor or ceiling ventilators. A grate fire was used to secure heat for curing. The only loss



TABLE II: *Results of Storage Tests.*  
Part I: Auburn Experiments.

| Year    | Variety Stored | Bushels in Storage House | Percent of loss by decay in house March 1st | Percent of loss by decay in house May 1st | Bushels stored in bank  | Percent of loss by decay in bank March 1st |
|---------|----------------|--------------------------|---------------------------------------------|-------------------------------------------|-------------------------|--------------------------------------------|
| 1914-15 | Triumph        | 24                       | 5.5                                         | None in Storage                           | 20                      | 100                                        |
|         | Nancy Hall     | 35                       | 11                                          | None in Storage                           | 20                      | 100                                        |
| 1915-16 | Triumph        | 107                      | 4                                           | 7                                         | 16                      | 11                                         |
|         | Nancy Hall     | 74                       | 5.8                                         | 7.4                                       | 10                      | 9                                          |
| 1916-17 | Triumph        | 60                       | .5                                          | 1.7                                       | 9                       | 10                                         |
|         | Nancy Hall     | 26                       | 2                                           | 5                                         | 9                       | 10                                         |
|         | Porto Rico     | 8 3-4                    | 2 8                                         | 3.5                                       | This Variety Not Banked |                                            |

Part II: Storage at Montgomery in cooperation with Mrs. Bellamy.

|         |         |     |     |                 |     |     |
|---------|---------|-----|-----|-----------------|-----|-----|
| 1915-16 | Triumph | 427 | 3   | 3.5             | 450 | 7.5 |
| 1916-17 | Triumph | 347 | 4.5 | None in Storage | 10  | 80  |

Part III. Storage at Greenville in cooperation with J. E. Helms.

|         |         |     |     |                                                          |  |  |
|---------|---------|-----|-----|----------------------------------------------------------|--|--|
| 1915-16 | Triumph | 200 | 2.5 | Reported average of community loss by decay in banks 45% |  |  |
| 1916-17 | Triumph | 300 | 1.5 |                                                          |  |  |

Part IV. Storage near Auburn in cooperation with J. A. Cullars.

|         |            |                    |    |                 |    |     |
|---------|------------|--------------------|----|-----------------|----|-----|
| 1914-15 | Nancy Hall | Did not have house |    |                 | 50 | 100 |
| 1915-16 | Nancy Hall | 100                | 10 | None in Storage | 15 | 80  |
| 1916-17 | Nancy Hall | 60                 | 2  | Would not bank  |    |     |

was in the lower corners of the bins farthest from the grate, which indicates that the potatoes in that portion of the bins may not have been properly cured.

The storage at Greenville, Table II, Part 3, in cooperation with Mr. J. E. Helms, gave excellent results with an average loss of only 2 percent for the two years. The house used by Mr. Helms was a worked-over out-house as shown in Fig. 8. Mr. Helms very kindly secured data on losses in his community from storing in banks, which was an average of 45 percent for the two

years. He stated that his average loss by banking his potatoes for the past twenty-five years had been 75 per cent and that he had saved more than enough the first year in the storage house to pay for it. He also stated that the house was worth its cost because of the increased richness and sweetness of the cured potatoes.

The results of the cooperative experiments with Mr. J. A. Cullars of Auburn, as recorded in Table II, Part 4, show a total loss of banked potatoes in 1914-15. In 1915-16 he built a small house holding one hundred bushels. The house was not properly ventilated for the first few days during curing, and this probably accounts for a part of his loss of ten percent from decay. However, this loss is small when compared with the loss of 80 percent occurring in banks. His average loss for two years by banking was 90 percent as compared with 6 percent loss in his storage house. Mr. Cullars stated that even if the percent of loss were the same, the house was worth its cost because of the better quality of the cured potatoes.

### STORAGE ROT

Sweet potatoes are subject to at least two types of decay in the storage house; Soft Rot (*Rhizopus nigricans* Ehr.) and Dry Rot (*Diaporthe batatis* (E. & H.) Hart and Field). If the potatoes are properly cured there is practically no danger of decay from Soft Rot. If they are over-cured there is danger of Dry Rot.

It should be stated at this time that the potatoes stored in these experiments were not sorted at gathering time. The small tubers and cut and bruised tubers were all stored together without sorting. If the small tubers and strings had been discarded, the decay would probably have been reduced to a mere fraction of that recorded, because in no instance was decay found on a tuber that did not show a cut or a bruise. If only sound marketable potatoes are put in a bin and they are properly cured, the loss from rots will be negligible.

### LOSS OF WEIGHT IN CURING

One hundred and twenty (120) pounds of Triumph potatoes were selected from the field when dug November 10th, 1915, placed in the storage house and a careful record was kept of their loss in weight.

TABLE III. *Loss in Weight.*

| Date    | Weight in<br>Pounds. | Weight<br>Lost | Percent<br>of Loss |
|---------|----------------------|----------------|--------------------|
| 1915    |                      |                |                    |
| Nov. 10 | 120.                 |                |                    |
| Nov. 11 | 118.2                | 1.8            | 1.5                |
| Nov. 12 | 117.                 | 3.             | 2.5                |
| Nov. 13 | 116.1                | 3.9            | 3.25               |
| Nov. 15 | 114.5                | 5.5            | 4.58               |
| Nov. 16 | 113.85               | 6.15           | 5.12               |
| Nov. 17 | 113.25               | 6.75           | 5.62               |
| Nov. 18 | 112.86               | 7.14           | 5.95               |
| Nov. 19 | 112.28               | 7.72           | 6.43               |
| Nov. 20 | 111.95               | 8.05           | 6.70               |
| Nov. 22 | 111.25               | 8.75           | 7.29               |
| Nov. 23 | 110.74               | 9.26           | 7.71               |
| Nov. 24 | 110.53               | 9.47           | 7.89               |
| Nov. 25 | 110.16               | 9.84           | 8.2                |
| Nov. 26 | 109.82               | 10.18          | 8.48               |
| Nov. 27 | 109.45               | 10.55          | 8.79               |
| Nov. 29 | 108.85               | 11.15          | 9.29               |
| Nov. 30 | 108.65               | 11.35          | 9.45               |
| Dec. 1  | 108.40               | 11.60          | 9.66               |
| Dec. 2  | 108.20               | 11.80          | 9.83               |
| Dec. 3  | 108.                 | 12.            | 10.                |
| Dec. 4  | 107.70               | 12.30          | 10.23              |
| Dec. 6  | 107.20               | 12.80          | 10.66              |
| Dec. 7  | 107.                 | 13.            | 10.83              |
| Dec. 8  | 106.85               | 13.15          | 10.96              |
| Dec. 9  | 106.40               | 13.60          | 11.33              |
| Dec. 10 | 106.10               | 13.90          | 11.5               |
| Dec. 11 | 105.80               | 14.20          | 11.83              |
| Dec. 13 | 105.55               | 14.45          | 12.04              |
| Dec. 14 | 105.10               | 14.90          | 12.41              |
| Dec. 16 | 104.80               | 15.20          | 12.66              |
| Dec. 20 | 103.80               | 16.20          | 13.5               |
| Dec. 21 | 103.30               | 16.70          | 13.91              |
| Dec. 23 | 103.15               | 16.85          | 14.04              |
| Dec. 24 | 103.                 | 17.            | 14.16              |
| Dec. 25 | 102.85               | 17.15          | 14.29              |
| Dec. 27 | 102.35               | 17.65          | 14.7               |
| Dec. 30 | 102.                 | 18.            | 15.                |
| 1916    |                      |                |                    |
| Jan. 1  | 101.                 | 19.            | 15.83              |
| Jan. 14 | 99.                  | 21.            | 17.66              |
| Feb. 1  | 95.                  | 25.            | 19.83              |
| Feb. 14 | 93.80                | 26.20          | 21.83              |
| Mar. 13 | 90.10                | 29.90          | 24.92              |

A set of standard scales weighing to the one-hundredth of a pound, was used to secure the above data. The package which was of slatted construction, was placed on the scales in the storage room and was not removed until the end of the experiment.

The first five days show a loss of 5.5 pounds moisture with an average temperature of 84 F., while during the next five days under an average temperature

of 62 F., there was an additional loss of only 2.22 lbs., or only 40 percent of the rate during the first five days at the higher temperature. Notice chart of November, 1915, when the temperature was low and the humidity high, the loss of moisture was lowest, as shown November 20, 24, 30, December 34 and 27 to 30.

The evaporation of excess water immediately following storage constitutes curing. The rate of evaporation is evidently influenced by the percentage of excess moisture in the potato and also by the temperature and percent of moisture in the air at any time.

### HEATING AND VENTILATING

For the first two years a large, sheet-iron wood stove was used for producing heat. This type of stove is very hard to regulate. If too much draft is given, the stove is soon red-hot; if too little draft is given, combustion ceases and the room cools rapidly. These facts are evidenced by the extreme high and low temperatures as shown by records during the first year and a similar temperature record for the second year, except that, apparently due to the repair made to the ceiling, the room did not cool quite as much at night. There was greater uniformity of both temperature and humidity for the third period due to better construction, to the use of the coal stove and to the less frequent opening of the storage room. The superior results secured during the third year indicate that it is better not to open the house or to build fires as often as had been done during the previous two years. In the third year after the curing period fires were built but twice as a protection against freezing temperature and the room was rarely ventilated except for the few moments when visitors were shown into the building and when the temperature and humidity records were made at the end of each week.

The cost of fuel for heat the third year to cure the potatoes stored in house shown in Fig. 3 was about two dollars.

### HUMIDITY

The humidity records show that the degree of humidity at no time passed the ninety degree mark and that during the third year, when the crop kept better than at any other period, the degree of humidity was almost constantly at or between 80 and 90 degrees. It is entirely likely that if the cur-

ing has been perfectly done at the curing period, a lower degree of humidity would cause a constant loss of moisture in the potatoes to a greater degree than would be desirable. Therefore, the practice of opening the house on warm, dry days during the first two seasons, thus admitting the dry air from the outside, was of doubtful value.

The atmosphere in the bank often reaches the point of saturation as shown by sweating. But our records show that in the house the air is usually twenty percent short of saturation. And the weight table shows a gradual loss of moisture in cured stored potatoes throughout the storage period.

Practical growers claim that potatoes stored in banks are inclined to become "watery" during the warm, late winter weather, thus not only lowering the quality of the potato for use as food, but increasing the probability of decay.

### SUMMARY

The results of these experiments seem to show that potatoes can be cured sufficiently in ten days to two weeks, but there is a continuous loss of moisture even when the humidity is from eighty to ninety degrees.

There is a vast difference between a banked potato and a cured potato stored in a dry room. The latter is sweeter and firmer and will undoubtedly ship to any reasonable distance by freight. Potatoes cured at Auburn the past winter were mailed to Honolulu, Hawaiian Islands, a distance of three thousand miles by rail and two thousand miles by boat, and requiring nearly a month for the trip, arrived in good condition and were bedded for plants with excellent results. A Triumph potato of the 1915 crop is lying in the office on this date, August 25th, 1917, and sending out good sprouts. There are many of the 1916 crop on hand in perfect condition for food or bedding.

A part of the 1916 crop was canned in February and made a fair canned product, although not as clear in color as the freshly dug potatoes.

Storage potatoes, because of their excellent condition and freedom from decay, are superior for bedding to those kept in banks.



## PLANS AND SPECIFICATIONS FOR A HOUSE, 20x20 FEET WITH 1250 BUSHELS CAPACITY

The following suggestion for the building of a new storage house will prove valuable to those who have no house that can be remodeled.

Plans for constructing a new house are shown in Figs. 1 and 2. Good material should be used in building the frame work of the house as it must support considerable weight when the house is filled. A row of brick, or cement, pillars should be placed ten feet apart under each side and under the middle of the house. These pillars should be at least eighteen inches high so as to give good ventilation under the building. The sills should be six by eight inches and the joists two by eight inches, or two by ten inches and free of knots. If the house is to be weather boarded the studding should be placed two feet apart, while if the house is planked up and down, the studding may be further apart with two lines of purlins running around the house, properly spaced between sill and plate. In Alabama, except in the Northern portion, a house built with building paper tacked on the studding inside and out and ceiled inside with flooring and planked up and down on the outside with cracks stripped, will be sufficiently warm. Those preferring a warmer house should put on storm sheeting on the outside of the two by fours, building paper and weather boarding.

The floor and ceiling should be double, with paper between. The first floor may be made of six or eight inch boards with edges fitting close together. The second floor should be of matched lumber, tongued and grooved and laid at right angles to the first. If the roof is constructed by using boards, with edges close for sheeting and covered with rubber roofing so as to prevent the air coming in, a single ceiling with paper is sufficient.

The floor should extend out against the outside wall in order to make a perfect dead air space and prevent rats getting between the walls. Do not fill the space between the walls with sawdust, or other materials, as the dead air space is better.

The plan as shown in Fig. 1 should have a door at one end and a window at the other. If a larger house is built a door should be placed at either end. The bins should be placed four inches from the walls at the back of the bins and six inches at the side of the bins,

so as to allow circulation of air. A little more room is required at the sides so as to open and close the floor ventilators. Some plans call for eighteen inches of space at the end of the house between walls and bins so that the ventilators may be opened and closed by hand. By making a long handle of one inch by one inch strip and attaching to ventilator, the ventilators may be opened and closed from the passage way, thus giving bin space for one hundred and eighty bushels of potatoes.

In a twenty by twenty foot house there should be a ventilator in each corner of the house, as shown in Fig. 1. These ventilators should be six inches wide and twelve to fifteen inches long and fit with a sliding lid that may be opened or closed at will. An eight by eight inch or ten by ten inch ventilator should be placed overhead in center of room, as shown in Fig. 3, and covered to keep out the rain. These are easily made by nailing together in box fashion and extending the box through the ceiling and roof. The lower end of the box should be provided with a closely fitting door or shutter which may be closed when desired.

The following is a list of material necessary to build a sweet potato storage house as shown in Figs. 1 and 2:

|           |                                        |          |
|-----------|----------------------------------------|----------|
| 8 pieces  | 4x4 x10 posts                          | 100 ft.  |
| 74 pieces | 2x4 x10 studding                       | 493 ft.  |
| 5 pieces  | 6x8 x20 sills                          | 400 ft.  |
| 11 pieces | 2x8 x20 floor joists                   | 294 ft.  |
| 11 pieces | 2x6 x20 ceiling joists                 | 220 ft.  |
| 32 pieces | 2x4 x12 rafters and purlins            | 256 ft.  |
| 90 pieces | 1x12x10 outside boards                 | 900 ft.  |
| 90 pieces | 1x3 x10 strips for outside wall        | 225 ft.  |
| 90 pieces | 1x6 x20 rough floor and ceiling boards | 900 ft.  |
| 30 pieces | 1x12x20 sheathing for roof             | 600 ft.  |
|           | *Ceiling and flooring                  | 2000 ft. |

2400 sq. ft. of building paper.

5 squares of rubber roofing.

1 stove.

Hinges for doors and windows.

400 brick for flues and pillars.

50 pounds of nails.

1 flue hanger.

2 loads of edging strips for bins.

Approximate cost of material, \$145.00.

\*For ceiling and flooring use second grade flooring as it is cheaper and much more satisfactory. Cut out all unsound knots.

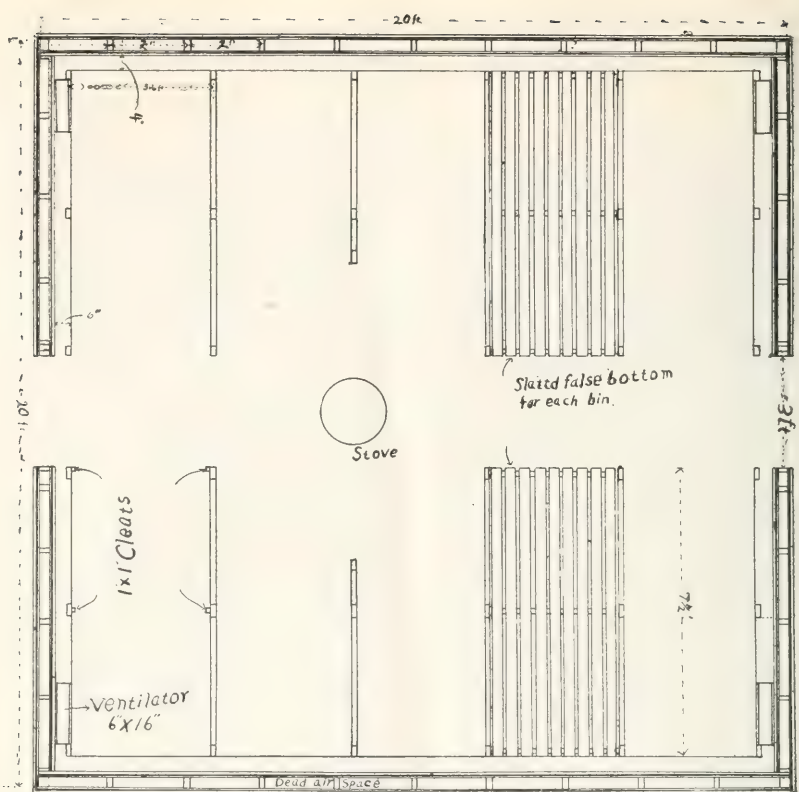


Fig. 1. Floor plan, 20x20 curing and storage house. Capacity, 1250 bushels.

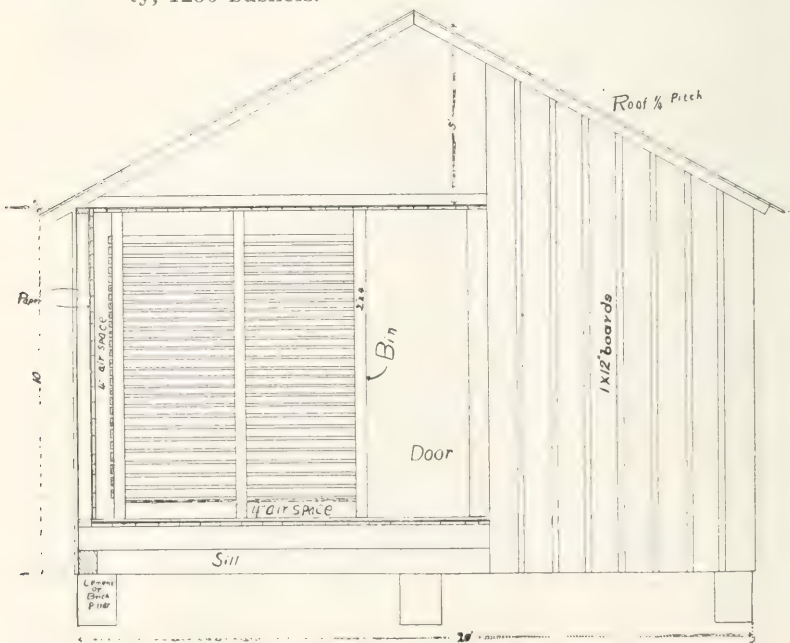


Fig. 2. End section of storage house in detail.



Fig. 3. Negro cabin on Station farm converted into storage house for experimental storage. Chimney used instead of building a new flue over the stove. Total cost, including stove, \$42.00.

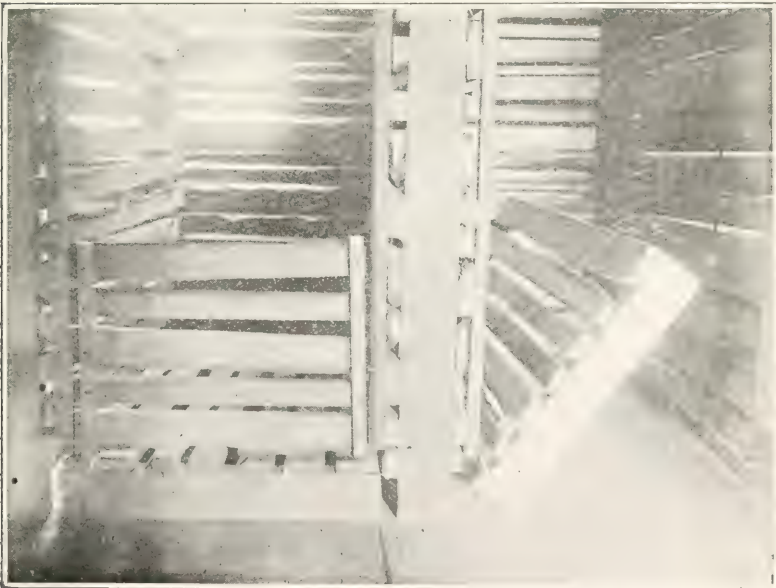


Fig. 4. Bins, showing end of gates and removable slatted bottom. Note saw mill edging strips used for constructing these bins.





Fig. 5. A good digging outfit.



Fig. 6. Note perfect healing of cuts and bruises. Photo eight months after placing in storage.





Fig. 7. Triumph potatoes in bin June 1st, 1916. Note cut ends which healed perfectly. Photo eight months after storing. This bin of potatoes was marketed in perfect condition in June.



Fig. 8. Storage house used by J. E. Helms, Greenville, Ala.  
Note double door, flue and ventilator.



Fig. 9. Hay rake method used at Auburn to remove vines.

**ALABAMA**  
**Agricultural Experiment Station**  
**OF THE**  
**Alabama Polytechnic Institute**  
**AUBURN**

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**Part I.**

**Velvet Beans Compared with Cottonseed Meal  
for Fattening Steers**

**Part II.**

**Velvet Beans, Cottonseed Meal and Corn as  
Feeds for Dairy Cattle**

**Part III.**

**Velvet Bean Pasture Compared with Corn and  
Dried Blood; Velvet Bean Meal Compared  
with Corn for Fattening Hogs**

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**By**  
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**and**  
**ERNEST GIBBENS**

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# VELVET BEANS COMPARED WITH COTTONSEED MEAL FOR FATTENING STEERS

By  
GEO. S. TEMPLETON  
AND  
ERNEST GIBBENS

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## INTRODUCTION

A crop of velvet beans grown with a crop of corn increases very materially the amount of concentrated feeds and roughage for the live stock on the farm. A very satisfactory method of harvesting the two crops is to gather the corn, after a heavy frost has killed the velvet bean vines, and then turn enough cattle and hogs into the field to consume the beans, the leaves and vines, and a large amount of the corn stover. This method of harvesting the two crops is satisfactory on soils of a sandy or light character which will not be injured by tramping of the stock during wet weather.

A number of farmers who grow velvet beans on a large scale make a practice of gathering the mature beans, after a heavy frost has killed the vines, and then allow the cattle and hogs to gather the immature beans. The mature beans are then used for feed later in the winter, or are sold on the market. The feeding of the velvet beans on the farm is generally preferable to selling them on the market. If the crop is fed to live stock about eighty-five percent of the fertilizer in the crop will be returned to the soil, and the commercial fertilizer bill will be reduced materially. However, this year there is not enough live stock in the section of the state growing velvet beans to consume the crop. The bean crop this year in Alabama is estimated at nearly 2,500,000 acres. As a large amount of the crop must be sold on the market it is very desirable to know how velvet beans as a concentrate compare with some of the common feeds used on the average farm. The experiments reported in this bulletin were planned to answer such questions.

Bulletin No. 192 issued by this Station in November, 1916, gives a report of a feeding test conducted during the winter of 1915-16 to compare the feeding value



of cottonseed meal with velvet beans for fattening steers.

The results of the feeding test for the winter of 1916-17 are not directly comparable to the ones given in Bulletin No. 192, as the steers used the two winters were somewhat different in quality and the beans were prepared in a different way.

#### OBJECT OF THE EXPERIMENT

This experiment was planned with a view of determining the relative feeding value of velvet beans in the pod and cottonseed meal as the concentrate part of a ration for fattening steers.

The steers were divided into two lots of fifteen each, and were given the following feeds:

LOT 1. Velvet beans in pods. Corn silage.

LOT 2. Cottonseed meal. Corn silage.

#### THE CATTLE

The steers used in this experiment were grades, showing either Angus, Hereford, or Shorthorn blood. About one-half of the steers were raised on the farm where the experiment was conducted; and the remainder were purchased in Texas in June, shipped to Allenville, and grazed during the summer. They then varied from one to two years in age. The average weight of each animal at the beginning of the test was approximately 773 pounds.

#### GENERAL PLAN OF THE WORK

The steers were fed under average farm conditions. The feeding test was conducted on the farm of Judge B. M. Allen, at Allenville, Alabama. Judge Allen furnished the cattle and the feeds, and the experiment was planned and carried on under the supervision of the authors of this Bulletin. Mr. Ernest Gibbens had personal charge of the cattle throughout the experiment.

The feed lots were located in a cedar grove. The cedar trees gave all the protection the steers had during the experiment. The lots had a southern exposure and were well drained. The manure was hauled out of the lots every few days. No bedding was used, but the lots were dry enough so the steers could lie down comfortably. Pure water from a deep well was kept before the steers at all times. Rock salt was kept in the feed troughs continually.

The steers were fed twice each day. The concentrates and roughage were mixed thoroughly by hand

in the feed troughs. The amount of feed was regulated so that it was consumed in a few hours. At the close of the test the steers were shipped to the St. Louis market.

#### PRICE AND CHARACTER OF FEEDS USED

The prices used in this bulletin are the prices actually paid for the steers and the feeds. The corn silage was made on the farm. The silage corn would have yielded twenty-five bushels of corn per acre. All of the feeds were of good quality. The corn silage was bright. The cottonseed meal was fresh, bright, and of a high grade. The velvet beans were well matured and of good quality. The prices of feeds were as follows:

|                           |                  |
|---------------------------|------------------|
| Cottonseed meal -----     | \$38.00 per ton. |
| Velvet beans in pod ----- | 20.00 per ton.   |
| Corn Silage -----         | 3.00 per ton.    |

#### METHOD OF FEEDING AND HANDLING THE STEERS

As the pastures began to fail in the fall the steers had the run of the stalk fields. They were in the stalk fields during the month of November. Eighteen days previous to going on the experiment the steers were fed, while in the stalk fields, two pounds of velvet beans and twelve pounds of corn silage per head per day. The preliminary feeding was done to accustom them to feeding and handling and to secure a uniform fill. On December 21st, 1916, the steers were weighed, tagged, and divided into the lots for the test. Each steer was weighed three consecutive days and the average of the three weights used as the initial weight of the steer in the test. Fourteen days later they were weighed by lots, and on the twenty-eighth day individual weights were taken, this procedure being repeated until the end of the test. The experiment continued for 119 days. Hence the steers were fed for 137 days, including the preliminary period.

The following table outlines by twenty-eight day periods the amount of feed given each steer daily:

TABLE I.—*Showing the Average Amount of Feed Consumed Daily Per Steer, December 21, 1916 to April 19, 1917, (119 Days).*

| PERIOD      | LOT I                                           | LOT II                                        |
|-------------|-------------------------------------------------|-----------------------------------------------|
|             | Velvet beans<br>Corn Silage                     | Cottonseed Meal<br>Corn silage                |
|             | Lbs.                                            | Lbs.                                          |
| 1st 28 days | Velvet beans --- 4.57<br>Corn silage --- 33.00  | Cottonseed meal 1.57<br>Corn silage --- 37.64 |
| 2nd 28 days | Velvet beans --- 9.43<br>Corn silage --- 27.46  | Cottonseed meal 4.37<br>Corn silage --- 41.02 |
| 3rd 28 days | Velvet beans --- 13.54<br>Corn silage --- 24.64 | Cottonseed meal 6.78<br>Corn silage --- 44.00 |
| 4th 28 days | Velvet beans --- 14.00<br>Corn silage --- 26.00 | Cottonseed meal 7.00<br>Corn silage --- 46.14 |
| Last 7 days | Velvet beans --- 14.00<br>Corn Silage --- 26.00 | Cottonseed meal 7.00<br>Corn silage --- 49.19 |

The beans were fed in the pod and were thoroughly mixed with the silage in the trough so that each steer would get only his share of the beans. After the experiment continued four weeks the beans were soaked in the pod in water for twelve hours previous to being fed. The soaking period softened the pod and seemed to assist the steers in masticating the beans.

The steers in Lot I ate on an average 4.57 pounds of velvet beans and 33 pounds of silage during the first 28 days. The amount of beans was gradually increased until the fourth period when each consumed 14 pounds of velvet beans and 26 pounds of silage. The steers in Lot I did not consume as much silage as the steers in Lot II.

The steers in Lot II ate on an average 1.57 pounds of cottonseed meal and 37.64 pounds of corn silage daily during the first twenty-eight days. The amount of meal was gradually increased until at the close of the experiment each steer was eating 7 pounds of cottonseed meal each day.

Both rations were relished by the steers and at no time during the test was there any trouble due to steers going off feed.

TABLE II.—*Average Weights and Gains December 21 1916 to April 19, 1917, (119 Days).*

| LOT | Number of Steers | RATION                         | Average Initial weight | Av. final weight of each steer | Av. total gain of each steer | Av. daily gain of each steer |
|-----|------------------|--------------------------------|------------------------|--------------------------------|------------------------------|------------------------------|
| I   | 15               | Corn silage<br>Velvet beans    | Lbs.<br>773.4          | Lbs.<br>963.73                 | Lbs.<br>190.34               | Lbs.<br>1.6                  |
| II  | 15               | Corn silage<br>Cottonseed meal | 777.73                 | 963.26                         | 185.51                       | 1.55                         |

All the steers in each lot made satisfactory gains, although they were not unusual. The average gains daily, per head, for the 119 days were 1.6 pounds and 1.55 pounds in Lot I and Lot II respectively.

At the close of the test the steers were shipped to the St. Louis market and sold to one of the packing companies. The steers were sold by lots to the buyer for the packing company, the buyer having no knowledge of how the steers were fed. The authors of this bulletin could not gather the data on the carcasses as the packing houses were closed to the public on account of the unusual conditions caused by the war. The packer stated, however, that the carcasses of Lot I (bean fed steers) showed a little better external covering of fat.

#### QUANTITY AND COST OF FEED REQUIRED TO MAKE ONE HUNDRED POUNDS GAIN

In a feeding operation the real value of a feed, or combinations of feeds, is measured by the number of pounds of feed required to make one hundred pounds of gain in live weight. Table III shows the quantity of feed required to make one hundred pounds of gain and the cost of gains under the conditions of this experiment.

TABLE III.—*Quantity and Cost of Feed to Make One Hundred Pounds of Gain, December 21, 1916 to April 19, 1917, (119 Days).*

| LOT | RATION              | Pounds of feed to make 100 lbs. gain | Cost of feed to make 100 lbs. gain |
|-----|---------------------|--------------------------------------|------------------------------------|
| I   | Velvet beans in pod | 670                                  | \$9.30                             |
|     | Corn silage         | 1733                                 |                                    |
| II  | Cottonseed meal     | 327                                  | \$10.42                            |
|     | Corn silage         | 2811                                 |                                    |

When the feeds are valued as previously stated it is seen that velvet bean fed steers made the cheapest gains. Lot I, however, consumed only about two-thirds as much silage as did Lot II. It is evident that the pods tended to reduce the consumption of silage. In this test 2.05 pounds of velvet beans in the pod were equal to 1 pound of high grade cottonseed meal. That is, according to this experiment, a feeder could afford to pay nearly half as much per ton for unhulled and unground velvet beans as for a ton of high grade cottonseed meal.



Although the results given in Bulletin No. 192 cannot be compared completely with the results of this experiment, as the cattle were different in quality and the beans were fed dry in the pod, the results will be of interest. In the test of the winter of 1915-16 one pound of cottonseed meal took the place of two and one-half pounds of velvet beans in the pod. The cost per 100 pounds of gain was practically equal when cottonseed meal cost \$35.00 per ton and unhulled velvet beans \$18.00 per ton. In feeding velvet beans in pods with silage it was then found that it was not necessary to grind the beans. The gains made by the steers were satisfactory. Lot 6 (cottonseed meal) gained an average of 1.6 pounds per day; Lot 7 (velvet beans) gained an average of 1.5 pounds per day.

#### FINANCIAL STATEMENT

The statement for the feeding test is based on the prices the steers actually cost and the local prices for feeds. Steers of the same age and quality, fed under similar conditions, should return the same profits on the same rations. Prices of steers and of feeds vary from year to year, so the feeder must make corrections in his estimate for feeding operations on the basis of local prices.

##### LOT I.—*Velvet Beans and Corn Silage:*

|                                                   |           |
|---------------------------------------------------|-----------|
| To 15 steers, 11,601 lbs. at 6c                   | \$ 696.06 |
| To 19,130 lbs. velvet beans at<br>\$20.00 per ton | 191.30    |
| To 49,484 lbs. corn silage at \$3.00 per ton,     | 74.22     |
| To freight, yardage and commission                | 49.65     |

TOTAL EXPENSE -----\$1011.23

|                                                      |         |
|------------------------------------------------------|---------|
| By sale 15 steers, 13,390 lbs.<br>at \$9.75 per cwt. | 1305.52 |
| TOTAL PROFIT                                         | 294.29  |
| PROFIT PER STEER                                     | 19.62   |

##### LOT II.—*Cottonseed Meal and Corn Silage*

|                                                     |           |
|-----------------------------------------------------|-----------|
| To 15 steers at 6c per lb.                          | \$ 699.96 |
| To 9,120 lbs. cottonseed meal at<br>\$38.00 per ton | 173.28    |
| To 76,795 lbs. corn silage at \$3.00 per ton,       | 115.19    |
| To freight, yardage and commission                  | 49.65     |

TOTAL EXPENSE -----\$1038.08

|                                                      |         |
|------------------------------------------------------|---------|
| By sale 15 steers, 13,660 lbs.<br>at \$9.40 per cwt. | 1284.04 |
| TOTAL PROFIT                                         | 245.96  |
| PROFIT PER STEER                                     | 16.39   |



## SUMMARY STATEMENTS

1. The steers used in this test were from one to two years old. They were grade Angus, Hereford, and Shorthorn.

2. At the beginning of test they averaged about 775 pounds.

3. The thirty head of steers were divided into two lots and fed as follows:

LOT I. Velvet beans in the pod. Corn silage.

LOT II. Cottonseed meal. Corn silage.

4. For the 119-day feeding period average daily gains of 1.6 and 1.55 pounds were secured in Lots I and II respectively.

5. It cost \$9.30 and \$10.42 to make 100 pounds of gain in Lots I and II respectively.

6. The steers cost 6c per pound when they were put in the feed lot. At the close of the experiment they were sold in St. Louis. The velvet bean steers sold for \$9.75 per hundred weight, and the cottonseed meal steers for \$9.40 per hundred weight.

7. Each steer in Lot I (velvet beans) netted a clear profit of \$19.62; and Lot II (cottonseed meal), \$16.39.

8. The velvet bean ration was relished by the steers.

9. In this experiment one pound of cottonseed meal took the place of 2.05 pounds of velvet beans in the pod. The velvet bean lot, however, required only approximately two-thirds as much silage as the cottonseed meal lot.

# PART II.

## VELVET BEANS VERSUS COTTONSEED MEAL AS FEEDS FOR DAIRY CATTLE

By  
GEO. S. TEMPLETON  
AND  
H. C. FERGUSON

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### INTRODUCTION

Due to the greatly increased production of velvet beans in recent years dairymen are becoming interested in the crop as a possible means of furnishing an economical home grown concentrate. The bean crop is nearly always planted with a crop of corn. With apparently no injury to the corn crop they will yield from one-half to one ton of beans to the acre, besides making a heavy vine growth. Henry and Morrison in "Feeds and Feeding," give them the following value in digestible nutrients per one hundred pounds, compared with corn and cottonseed meal:

|                                 | Protein | Carbohydrates | Fat |
|---------------------------------|---------|---------------|-----|
| Velvet bean, seed .....         | 18.1    | 50.8          | 5.3 |
| Velvet bean, seed and pod ..... | 14.9    | 51.7          | 3.8 |
| Good cottonseed meal .....      | 31.6    | 25.6          | 7.8 |
| Dent Corn .....                 | 7.5     | 67.8          | 4.6 |

It will be seen from the above that velvet beans contain more digestible carbohydrates and less protein and fat than good cottonseed meal, but more protein and less carbohydrates than dent corn, while the hulled beans contain more fat and the unhulled beans less fat than corn. With these facts in mind the following experiments were planned to determine their actual feeding value for dairy cattle.

### EXPERIMENT A

#### OBJECTS OF EXPERIMENT

The objects of this experiment, made in the winter of 1915-16, were to determine the relative value of velvet beans and pods as compared with a mixture of seven parts corn meal and eight parts cottonseed meal, as influencing:

1. The production of milk.
2. The production of butterfat.
3. The feed cost of milk and butterfat.

#### 4. The weight of cows in milk.

The cows used were pure bred Jerseys of only average productive ability. In selecting them attention was paid to the milk flow, length of time in milk, size, and age.

#### PLAN OF THE EXPERIMENT

Two lots of five cows each were used in the experiment. They were fed during a fourteen day preliminary period to accustom them to the rations. They were then fed for a twenty-eight day test period as follows:

LOT I received a mixture of corn meal, 7 parts, and high grade cottonseed meal, 8 parts, with corn silage

LOT II received velvet beans and pods, ground, and corn silage.

At the close of this period seven days were used to reverse the rations of the two lots.

For the second twenty-eight day test period they were fed as follows:

LOT I received velvet beans and pods, ground, and silage.

LOT II received a mixture of corn meal, 7 parts, and high grade cottonseed meal, 8 parts, with silage.

#### FEEDS USED

The feeds used were all of good quality. The shelled corn was ground into a coarse meal. The beans in the pods were found to be approximately one-third pods and two-thirds beans by weight, and were fed on the basis of the shelled beans—that is, one and one-half pounds of beans and pods were considered to be the equivalent of one pound of beans.

The mixture of corn meal and cottonseed meal was fed at the rate of one pound for each two and one-half pounds of milk produced, while the beans and pods were fed at the rate of one and one-half pounds for each two and one-half pounds of milk produced, as explained before. The silage was made of corn cut in the dent stage. Silage was the only roughage used and the cows were given all they would consume. Water was kept before the cows at all times and salt was given them at regular intervals. Cottonseed meal or a mixture of corn meal and cottonseed meal is generally used in this section for the concentrate part of a ration for dairy cows. It was the desire to make a com-

parison between the velvet beans and a mixture of the other two feeds, and still have the cottonseed meal predominate in the latter. Hence the proportion of seven parts corn meal to eight parts cottonseed meal. The prices of the feeds were as follows:

|                      |       |                 |
|----------------------|-------|-----------------|
| Cottonseed meal      | ----- | \$38.00 per ton |
| Corn                 | ----- | .85 per bu.     |
| Velvet beans in pods | ----- | 18.00 per ton   |
| Silage               | ----- | 2.50 per ton    |

#### METHOD OF FEEDING AND HANDLING THE COWS

Throughout the experiment the cows were confined to a small wooded lot so that the only feed they received was that given them. They were put in the Station barn morning and evening at regular intervals for feeding and milking. The cows were weighed every two weeks during each test period. The rations of the two lots were reversed at the close of the first period to eliminate the effects of individual variation between the two lots.

TABLE NO. I.—*Showing Total Amount of Feed Consumed and Amount of Milk and Butterfat Produced. — (56 Days).*

| Concentrates         | Grain  | Silage  | Milk produced | Butterfat produced |
|----------------------|--------|---------|---------------|--------------------|
|                      | Lbs.   | Lbs.    | Lbs.          | Lbs.               |
| Velvet beans in pods | 2054.8 | 10301.7 | 4753.5        | 229.40             |
| Corn meal, 7 parts   | 1124.0 | 10813.7 | 5243.1        | 267.49             |
| Cot's'd meal, 8 pts. | 1284.3 |         |               |                    |

Table I shows that more feed was consumed by the cows while on the cottonseed meal and corn ration, and that more milk was produced by that feed. The beans were first fed in the pod with no preparation, but the cows did not seem to relish them in this form. They were then ground into a coarse meal, but even with this treatment the results were not altogether satisfactory, as none of the cows relished the beans sufficiently to consume their entire ration. However, some of the cows seemed to develop a liking for the beans towards the close of the experiment. A great deal of difference was observed between individual cows in this respect. The maximum consumption was eleven pounds per day, while the minimum consumption was nearly four pounds per day, per cow. The cows consuming a heavy ration kept up their milk flow as well on the beans as on the cottonseed meal mixture.

TABLE NO. II.—*Showing the Amount of Feed Required for, and Feed Cost of, 100 Lbs. of Milk and 1 Lb. of Butterfat.*

| Concentrates                               | 100 Lbs. Milk |               |      | 1 Lb. Butterfat |              |      |
|--------------------------------------------|---------------|---------------|------|-----------------|--------------|------|
|                                            | Grain         | Silage        | Cost | Grain           | Silage       | Cost |
| Velvet beans in pods                       | Lbs.<br>43.2  | Lbs.<br>216.7 | 66   | Lbs.<br>8.9     | Lbs.<br>44.9 | 13   |
| Corn meal, 7 parts<br>Cot's'd meal, 8 pts. | 21.4<br>24.4  | 208.1         | 1.05 | 4.2<br>4.8      | 40.4         | 205  |

The above table shows that it required practically the same amount of ground velvet beans and pods to produce one hundred pounds of milk and one pound of butterfat as it did of the mixture of corn meal and cottonseed meal. It is also shown that the feed cost is cheaper in each case with the velvet bean and pod ration. However, Table I shows that the production of milk is 10 per cent. greater and butterfat 16 per cent. greater with the grain mixture. Table III, following, shows that the cows eating the velvet bean and pod ration lost an average of 2.9 pounds per cow during the 56 days, while those eating the mixture gained 24.6 pounds per cow.

TABLE NO. III.—*Showing the Influence of the Two Rations on the Weights of the Cows. (56 Days).*

| Concentrates                  | Av. weight at beginning | Av. weight at close | Average gain | Average loss |
|-------------------------------|-------------------------|---------------------|--------------|--------------|
| Velvet beans in pods          | 796.2 lbs.              | 793.3 lbs.          |              | 2.9 lbs.     |
| Corn meal and Cottonseed meal | 796.8 lbs.              | 821.4 lbs.          | 24.6 lbs.    |              |

The above table shows that the grain mixture was more efficient for maintaining the weight of dairy cows in milk than a ration of ground velvet beans and pods. However, observation and figures on the individual cows show that in the instances where the velvet beans were nearly all consumed the weights were maintained and some of the cows gained in weight.

#### SUMMARY

1. A grain ration of 7 parts corn meal mixed with 8 parts cottonseed meal, fed with corn silage, produced more milk and butterfat than ground velvet beans in pods with silage.

2. The velvet bean ration produced milk and butterfat at a lower cost than the corn meal and cottonseed meal mixture.



3. The velvet bean ration did not maintain the weights of the cows as well as the corn and cottonseed meal mixture.

4. The velvet beans and pods were not relished by most of the cows, whether unprepared or ground to a meal.

5. Wide variations were observed as to the palatability of the velvet bean ration with the different cows. The maximum consumption was eleven pounds per cow, per day, and the minimum consumption was nearly four pounds per head, per day.

6. Individual cows consuming a heavy ration of velvet beans maintained their milk flow and body weight.

## EXPERIMENT B

OBJECTS OF THE EXPERIMENT (Winter 1916-17).

1. A comparison of velvet bean and pod meal versus cottonseed meal as a supplement to corn for milk and butterfat production.

2. Influence of velvet bean and pod meal versus cottonseed meal as a supplement to corn on the cost of producing milk and butterfat.

3. Efficiency of velvet bean and pod meal versus cottonseed meal as a supplement to corn in maintaining the weights of cows in milk.

### COWS USED

The cows used were pure bred Jerseys of only average productive ability. Length of time in milk, amount of milk flow, size, and age were determining factors in the selection of the two lots.

### PLAN OF THE EXPERIMENT

Two lots of four cows each were used in this experiment. A preliminary period of seven days was taken to accustom them to the rations. They were then fed for twenty-eight days on the following rations:

LOT I received a mixture of 4 parts corn meal and 6 parts velvet bean and pod meal, and corn silage.

LOT II received a mixture of 4 parts corn meal and 3 parts high grade cottonseed meal, and corn silage.

At the close of the first period a seven day period was taken in which to reverse the rations of the two lots.

For a second twenty-eight day period Lot I received a ration of corn meal, 4 parts, and cottonseed meal, 3 parts, with corn silage, while Lot II received corn meal, 4 parts, and velvet bean meal, 6 parts, with corn silage.

#### FEEDS USED

All of the feeds used were of good quality. The corn was ground into a coarse meal as in the previous year. The beans in the pods were also ground into a coarse meal. The cottonseed meal was a good grade of meal containing 36 per cent protein (7 per cent ammonia). Figuring on the analysis from the protein basis velvet beans, seed and pods, are found to be about one-half as valuable as cottonseed meal of the above quality. As Experiment A had shown that the velvet beans in the pod were unpalatable to most of the cows, it was decided to add corn meal to the bean and pod ration to increase the palatability. The same amount of corn was fed to each lot so that the variable factor was the amount of velvet beans and cottonseed meal; these were in the proportion of two to one. Thirty pounds of corn silage was fed to each cow daily throughout the experiment.

The prices of the feeds were as follows:

|                 |       |                 |
|-----------------|-------|-----------------|
| Cottonseed meal | ----- | \$40.00 per ton |
| Velvet beans    | ----- | 22.50 per ton   |
| Corn            | ----- | 1.18 per bu.    |
| Silage          | ----- | 4.00 per ton    |

#### METHOD OF FEEDING AND HANDLING THE COWS

The cows all had the run of a small wooded lot during the entire period of the test. Water was kept before them at all times and salt was given at regular intervals. Milking and feeding was done twice daily in the Station barn. Individual weights of the cows were taken weekly. Records of production were kept by weighing the milk and making a Babcock test of each cow's milk at each milking.

TABLE NO. I.—*Showing Total Amount of Feed Consumed, and Amount of Milk and Butterfat Produced*

| Concentrates                                      | Ground<br>Velvet<br>beans | Cotton-<br>seed meal | Corn  | Silage | Lbs. milk<br>produced | Lbs. but-<br>terfat<br>produced |
|---------------------------------------------------|---------------------------|----------------------|-------|--------|-----------------------|---------------------------------|
|                                                   | Lbs.                      | Lbs.                 | Lbs.  | Lbs.   | Lbs.                  | Lbs.                            |
| Velvet beans<br>in pods, 6 parts<br>Corn, 4 parts | 1370.9                    |                      | 913.9 | 6720   | 3252.4                | 167.737                         |
| Cottonseed<br>Meal, 3 parts<br>Corn, 4 parts      |                           | 678                  | 894   | 6700   | 3418.1                | 174.103                         |

Table I shows that the ration containing velvet beans did not produce as much milk or butterfat as the ration containing cottonseed meal, when used in the proportion 2 to 1.

In agreement with the previous year's work, it was found that the velvet bean ration was not altogether palatable. It was also observed that individuality was a strong factor, one cow developing such a liking for the bean ration that she was not satisfied with the cottonseed meal ration when changed.

TABLE No. II.—*Showing Amount of Feed Required to Produce 100 Pounds of Milk and 1 Pound of Butterfat.*

| Concentrates                  | Feed for 100 Lbs. Milk |        |         | Feed for 1 Lb. Butterfat |        |        |
|-------------------------------|------------------------|--------|---------|--------------------------|--------|--------|
|                               | Grain                  | Silage | Cost    | Grain                    | Silage | Cost   |
|                               | Lbs.                   | Lbs.   |         | Lbs.                     | Lbs.   |        |
| Velvet beans in pods, 6 parts | 42.1                   |        |         | 8.1                      |        |        |
| Corn, 4 parts                 | 28.0                   | 206.6  | \$1.476 | 5.4                      | 40.0   | 28.45c |
| Cottonseed meal, 3 parts      | 19.8                   |        |         | 3.8                      |        |        |
| Corn, 4 parts                 | 26.1                   | 196.0  | \$1.336 | 5.1                      | 38.4   | 25.79c |

Table II shows that two parts of velvet beans in pods did not produce as much milk or butterfat as one part of cottonseed meal. The cottonseed meal at \$10.00 per ton was also more economical than were the velvet beans at \$22.50.

Based on the production of milk in this test, where 6 parts of velvet beans in pods were fed with 4 parts corn, the velvet beans were worth only \$15.80 per ton when cottonseed meal was worth \$40.00 per ton, the cottonseed meal being fed in proportion of 3 parts to 4 parts of corn.

On the same basis for butterfat production the beans were worth \$15.92 per ton.

TABLE No. III.—*Showing Ratio of Productive Value of Cottonseed Meal and Velvet Beans in Pods, Ground.*

| Price 1 Ton Cottonseed Meal | Relative Value 1 Ton Velvet Beans in Pods, Ground |
|-----------------------------|---------------------------------------------------|
| \$50.00                     | \$20.62                                           |
| 48.00                       | 19.68                                             |
| 45.00                       | 18.27                                             |
| 40.00                       | 15.80                                             |
| 35.00                       | 13.56                                             |
| 30.00                       | 11.21                                             |

From the above table an easy calculation shows that on an average two and one-half pounds of velvet beans with pods, ground were equal in feeding value and economy to one pound of good cottonseed meal.

TABLE NO. IV.--*Showing the Influence of the Two Rations on the Weights of the Cows. (56 Days).*

| Concentrates                                 | Av. weight at beginning | Av. weight at close | Average loss |
|----------------------------------------------|-------------------------|---------------------|--------------|
| Velvet beans in pods, 6 parts; Corn, 4 parts | 761.5 lbs.              | 758.12 lbs.         | 3.38 lbs.    |
| Cottonseed meal, 3 parts<br>Corn, 4 parts    | 763 2 lbs.              | 761.75 lbs.         | 1 45 lbs.    |

Table IV shows that the cows on each ration lost very slightly in flesh during the test. The loss was probably due to the weather conditions rather than to the feed. During the first period there was considerable cold, wet weather, and both lots lost in weight. During the second part of the test the weather was more favorable and both lots gained in weight.

#### SUMMARY

1. Cottonseed meal, 3 parts, mixed with corn meal, 4 parts, produced more milk and butterfat than ground velvet beans and pods, 6 parts, mixed with corn meal, 4 parts, when fed with silage.

2. The cottonseed meal mixture produced both milk and butterfat more economically than the velvet bean mixture, when velvet bean meal was priced at \$22.50 and cottonseed meal at \$40.00 per ton.

3. When cottonseed meal (36 per cent protein or 7 per cent ammonia) and velvet beans and pods were separately fed with corn in the proportions used in this experiment, the velvet beans were worth \$15.80 per ton for milk production, and \$15.92 per ton for butterfat production when the cottonseed meal was worth \$40.00 per ton.

4. The two rations were practically the same in efficiency in maintaining the weight of the cows.

5. The velvet bean ration was not palatable to all of the cows in the test. The milk flow was maintained by those cows consuming a full ration of the velvet beans.

6. On the basis of the experiment just fed above, two and one-half pounds of velvet beans with pods, ground, were equal in feeding value and economy to one pound of good cottonseed meal.

# PART III

## VELVET BEAN PASTURE COMPARED WITH CORN AND DRIED BLOOD; VELVET BEAN MEAL COM- PARED WITH CORN FOR FATTENING HOGS

BY  
GEO. S. TEMPLETON

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### INTRODUCTION

The farmers of Alabama are using the crop of velvet beans in two ways to feed their hogs. The most common method of utilizing the crop is to allow the hogs to "hog down" the bean crop after a heavy frost has killed the vines, and the corn crop has been gathered from the bean field. A number of farmers gather the mature beans and feed them later in the winter to the breeding herd of hogs or to the fattening hogs.

As the prices on concentrated feeds have advanced very rapidly in the past few years the following experiments were planned with a view of comparing the feeding value of the new crop with other concentrates commonly used for fattening hogs.

In the fall of 1914 arrangements were made with Dr. J. F. Yarbrough, of Columbia, Alabama, to feed some hogs on his farm. Dr. Yarbrough furnished the bean pasture, the feeds, and the hogs for the experiment. Mr. J. A. McLeod was stationed on the farm and had personal supervision of the experiment.

### OBJECT OF EXPERIMENT A

The object of this experiment was to compare velvet bean pasture with certain high priced concentrates (corn and blood meal) for fattening hogs.

### RATIONS AND THE VELVET BEAN CROP

Fifteen pigs used in this experiment were divided equally as to the breeding, quality, and size, into three lots of five each and fed as follows:

LOT I:      Corn, 10 parts,  
              Dried blood, 1 part.

LOT II:     Corn, 10 parts,                    (one-half ration (2 pounds to  
              Dried blood, 1 part (each 100 lbs. live weight).  
              Velvet bean pasture



LOT III:      Corn, 10 parts                    } one-fourth ration (1 pound to  
                 Dried blood, 1 part,       } each 100 pounds live weight).  
                 Velvet bean pasture.

The velvet beans were planted in the rows with the corn. The corn was gathered after frost, (October 27th). The yield of beans was estimated as a thirty percent crop. The poor yield was due to a poor stand, extremely dry weather during the greater part of the growing period, and to the early frost. As the bean crop was grown with the corn crop, the cost of labor to produce the combined crop and the rent of the land was divided equally with the two crops. The cost of the bean seed and labor of dropping the seed was charged to this crop. With the local price of labor of ten cents per hour for man labor, six cents per hour for boy labor, and five cents per hour for horse labor, and rent at \$3.00 per acre, the cost of producing an acre of beans amounted to \$2.83. On October 27th a heavy frost killed the bean vines. Two one-acre plots were fenced off and the experiment started on November 3rd. For several days the hogs did not relish the beans, but they gradually became accustomed to them and ate same with relish for the remainder of the experimental period.

## THE PIGS

The pigs used in this experiment were raised on the farm where the experiment was conducted. They were out of native sows and sired by a Berkshire boar. At the beginning of the experiment they averaged approximately 68 pounds.

## METHOD OF FEEDING

Lot I was confined in a dry lot and fed twice daily. Lots II and III had the run of one acre each of velvet bean pasture and were fed a one-half and one-fourth ration respectively of corn, ten parts, and blood meal, one part. The details of the experiment are shown in the following table:

*Velvet Bean Pasture Compared With Dry Lot Feeding  
Lots I and II (November 3rd to December 3rd,  
1914) 30 Days. Lot III (November 3rd to No-  
vember 26th, 1914) 23 Days.*

| LOT | No. of Pigs | RATION                                                                                  | Av. Initial weight | Av. final weight | Total Av. gain | Av. daily gain | Feed to make 100 lbs gain | Total cost to make 100 lbs. gain |
|-----|-------------|-----------------------------------------------------------------------------------------|--------------------|------------------|----------------|----------------|---------------------------|----------------------------------|
| I   | 5           | Corn, 10 Parts<br>Dried blood, 1 part<br>} Full Ration                                  | 70                 | 97.6             | 27.6           | .92            | 316<br>31.6               | \$6.59                           |
| II  | 5           | Corn, 10 parts<br>Dried Blood, 1 part<br>} One-Half Ration<br><br>Velvet Bean Pasture   | 67.2               | 95.8             | 28.6           | .95            | 150.07<br>15.007<br>.7 A  | \$4.91                           |
| III | 5           | Corn, 10 parts<br>Dried Blood, 1 part<br>} One-Fourth Ration<br><br>Velvet bean Pasture | 67.6               | 89.8             | 22.2           | .964           | 71.03<br>7.103<br>.9 A    | \$4.02                           |

The daily gains were satisfactory for the type of hogs used. The pigs were not finished when the experiment was closed, but this crop of beans was only one-third of an average crop, and an average crop would have fed the pigs for a period equal to three times the length of this test, which would have given a good finish to the pigs.

By examining the column showing the amount of grain for 100 pounds gain of each lot it will be seen that the bean crop saved considerable high priced concentrates.

In this experiment one-fourth ration of corn and dried blood produced larger daily gains, and produced the gains much cheaper than a one-half ration when the pigs were grazing the velvet bean field.

The grazing period in Lot III was a week shorter than in Lot II, as the amount of concentrates was much smaller in Lot III, and the pigs used up the bean crop much more quickly.

#### SUMMARY STATEMENTS

1. The 15 pigs used in this test were divided into three equal lots and given the following feeds:

|          |                                                                |                                                               |
|----------|----------------------------------------------------------------|---------------------------------------------------------------|
| LOT I:   | Corn, 10 parts<br>Dried blood, 1 part                          | } in dry lot.                                                 |
| LOT II:  | Corn, 10 parts,<br>Dried blood, 1 part<br>Velvet bean pasture. | } one-half ration (2 pounds to each 100 pounds live weight).  |
| LOT III: | Corn, 10 parts,<br>Dried blood, 1 part<br>Velvet bean pasture. | } one-fourth ration (1 pound to each 100 pounds live weight). |

2. The crop of velvet beans was only one-third of an average crop due to poor stand, dry weather during the growing season, and early frost on October 27th.

3. To make 100 pounds gain in live weight it required 316 pounds corn and 31.6 pounds dried blood in Lot I; 15.07 pounds corn and 15.007 pounds dried blood and .7 A. velvet beans in Lot II; and 71.03 pounds corn and 7.1 pounds dried blood with .9 A. velvet beans in Lot III.

4. When corn was worth \$1.00 per bushel, dried blood \$60.00 per ton and velvet bean pasture \$2.83 per acre, it cost \$6.59 to produce 100 pounds increase in weight in Lot I; \$4.91 in Lot II; and \$4.02 in Lot III.

5. The velvet bean crop proved to be entirely satisfactory as a hog feed. It should be remembered that a crop of corn was gathered from this area before the hogs were turned in.

#### OBJECT OF EXPERIMENT B

The object of this experiment was to compare a ration of corn with a ration of one-half corn and one-half velvet bean meal (threshed beans) to determine the value of the velvet bean meal as a supplement to corn for fattening hogs, and to study the effects of the velvet bean on the quality of carcass and the lard.

#### FEEDS AND METHOD OF FEEDING

The corn was ground into a coarse meal. The velvet bean meal was made by grinding the threshed velvet beans into a fine meal. The corn and bean meal were mixed together and enough water added to make a thin slop. The day's feed was divided into equal parts, the night and morning feeds being fed at regular hours. The corn was valued at \$1.00 per bushel, and the velvet bean meal at \$34.00 per ton.

*Corn Versus Corn One-half and Velvet Bean Meal One-half, December 27, 1916 to March 27, 1917, (90 Days).*

| LOT | No. of Hogs | RATION                                            | Av. Initial weight | Av. final weight | Av. total gain per pig | Av. daily gain | Feed to make 100 lbs. gain | Cost of 100 lbs. gain      |
|-----|-------------|---------------------------------------------------|--------------------|------------------|------------------------|----------------|----------------------------|----------------------------|
| I   | 5           | Corn alone                                        | 75                 | 149              | 74                     | .813           | Lbs.<br>483.57             | \$8.64                     |
| II  | 6           | Corn one-half, velvet bean meal one-half, no pods | 70                 | 128              | 58                     | .64            | 268.82<br>268.82           | \$4.80<br>\$4.57<br>\$9.37 |

The hogs were butchered at the close of the experiment and notes made of the carcass and the melting points determined for the lard from the kidney fat.

The fat of the velvet bean fed hogs was found to be slightly darker in color than the fat of the corn fed hogs. It was found that the lards of the corn fed hogs had on the average a melting point slightly higher than the bean fed hogs, although the carcasses of both lots were firm. The average melting point for the corn fed lot was 46.04 degrees C., and for the velvet bean fed lot, 44.35 degrees C.

#### SUMMARY STATEMENTS

1. The daily gains were not large, but satisfactory for the size of the pigs used in the experiment.

2. To make 100 pounds of increase in live weight required 483.57 pounds of corn in Lot I; 268.82 pounds of corn and 268.82 pounds of velvet bean meal or a total of 537.64 pounds in Lot II.

3. When corn was worth \$1.00 per bushel, and velvet bean meal \$34.00 per ton, it cost \$8.64 and \$9.37 to make 100 pounds of increased live weight in Lots I and II respectively.

4. The velvet bean fat was slightly darker than the corn fed carcasses.

5. The average melting point of the lard from Lot I was 46.04 degrees C.; for Lot II, 44.35 degrees C. All of the carcasses of both lots were firm.

Thirtieth Annual Report

OF THE

Agricultural Experiment  
Station

OF THE

Alabama Polytechnic Institute

Auburn, Alabama

January, 1918





Thirtieth Annual Report

OF THE

Agricultural Experiment  
Station

OF THE

Alabama Polytechnic Institute

Auburn, Alabama

January, 1918



ALABAMA POLYTECHNIC INSTITUTE

Auburn, Ala., Jan. 30, 1918.

Governor Charles Henderson,  
Executive Department,  
Montgomery, Ala.

Sir:

I have the honor herewith to transmit to you the Thirtieth Annual Report of the Agricultural Experiment Station of the Alabama Polytechnic Institute.

This report is made in accordance with the Act of Congress approved March 2, 1887, establishing agricultural experiment stations, and the Act of Congress approved March 16, 1906, known as the Adams Act.

Respectfully,  
CHAS. C. THACH,  
President.





Auburn, Ala., Jan. 29, 1918.

Dr. C. C. Thach, President,  
Alabama Polytechnic Institute,  
Auburn, Ala.

Sir:

I herewith submit the Thirtieth Annual Report of the Experiment Station of the Alabama Polytechnic Institute for the fiscal year ending June 30, 1917.

It contains the detailed report of the Director and Agriculturist, the Treasurer, the Chemist, The Veterinarian, the Botanist, the Horticulturist, the Entomologist, the Plant Pathologist, and the Animal Husbandman, for the year ending December 31, 1917.

Respectfully submitted,

J. F. DUGGAR,  
Director, Experiment Station.



Auburn, Ala., Jan. 29, 1918.

Dr. C. C. Thach, President,  
Alabama Polytechnic Institute,  
Auburn, Ala. .

Sir:

I herewith submit the Thirtieth Annual Report of the Experiment Station of the Alabama Polytechnic Institute for the fiscal year ending June 30, 1917.

It contains the detailed report of the Director and Agriculturist, the Treasurer, the Chemist, The Veterinarian, the Botanist, the Horticulturist, the Entomologist, the Plant Pathologist, and the Animal Husbandman, for the year ending December 31, 1917.

Respectfully submitted,

J. F. DUGGAR,  
Director, Experiment Station.



## AGRICULTURAL EXPERIMENT STATION

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|                                                   |                      |
|---------------------------------------------------|----------------------|
| His Excellency, Charles Henderson, President..... | Ex-Officio           |
| Spright Dowell, Superintendent of Education.....  | Ex-Officio           |
| A. W. Bell.....                                   | Anniston, Ala.       |
| Harry Herzfeld.....                               | Alexander City, Ala. |
| Oliver R. Hood.....                               | Gadsden, Ala.        |
| C. S. McDowell, Jr.....                           | Eufaula, Ala.        |
| W. K. Terry.....                                  | Birmingham, Ala.     |
| W. H. Oates.....                                  | Mobile, Ala.         |
| T. D. Samford.....                                | Opelika, Ala.        |
| R. F. Kolb.....                                   | Montgomery, Ala.     |
| J. A. Rogers.....                                 | Gainesville, Ala.    |
| C. M. Sherrod.....                                | Courtland, Ala.      |
| P. S. Haley.....                                  | Corona, Ala.         |

### COMMITTEE OF TRUSTEES ON EXPERIMENT STATION

|                         |             |
|-------------------------|-------------|
| R. F. Kolb.....         | Montgomery  |
| A. W. Bell.....         | Anniston    |
| J. A. Rogers.....       | Gainesville |
| C. S. McDowell, Jr..... | Eufaula     |



## STATION STAFF

C. C. THACH, President of the College  
J. F. DUGGAR, Director of Experiment Station

### AGRICULTURE:

J. F. Duggar, Agriculturist.  
E. F. Cauthen, Associate.  
M. J. Funchess, Associate.  
J. T. Williamson, Field Agt.  
H. B. Tisdale, Associate

Plant Breeder.

O. H. Sellers, Assistant.  
M. H. Pearson, Assistant.

### VETERINARY SCIENCE:

C. A. Cary, Veterinarian

### CHEMISTRY:

—————, Chemist,  
Soils and Crops.  
C. L. Hare, Physiological  
Chemist.

### BOTANY:

W. A. Gardner, Botanist.  
A. B. Massey, Assistant.

### PLANT PATHOLOGY:

G. L. Peltier, Plant Pathol-  
ogist.

### HORTICULTURE:

G. C. Starcher, Horticulturist.  
J. C. C. Price, Associate.  
C. L. Isbell, Assistant.

### ENTOMOLOGY:

W. E. Hinds, Entomologist.  
F. L. Thomas, Assistant.  
D. C. Warren, Field Agent.

### ANIMAL HUSBANDRY:

G. S. Templeton, Animal  
Husbandman.  
H. C. Ferguson, Associate.  
E. Gibbens, Assistant.  
V. W. Crawford, Assistant.

### AGRICULTURAL ENGINEERING:

R. U. Blasingame, Agricul-  
tural Engineer.

# REPORT OF HATCH AND ADAMS FUNDS FOR 1916-1917

## Receipts.

|                                        | Hatch       | Adams       |
|----------------------------------------|-------------|-------------|
| To amount from U. S. Treasury (Net) .. | \$15,000.00 | \$15,000.00 |

## Disbursements

|                                         |             |             |
|-----------------------------------------|-------------|-------------|
| By Salaries .....                       | \$ 7,437.35 | \$10,183.69 |
| By Labor .....                          | 1,996.02    | 1,540.38    |
| By Publications .....                   | 1,229.77    |             |
| By Postage and Stationery .....         | 214.46      | 109.37      |
| By Freight and Express .....            | 268.43      | 314.78      |
| By Heat, Light, Water and Power .....   | 464.70      | 294.20      |
| By Chemicals and Laboratory Supplies .. | 22.13       | 133.08      |
| By Seeds, Plants and Sundry Supplies .. | 431.96      | 137.56      |
| By Fertilizers .....                    | 491.92      | 156.25      |
| By Feeding Stuffs .....                 | 682.97      | 543.59      |
| By Library .....                        | 335.27      | 11.00       |
| By Tools, Machinery and Appliances ...  | 339.50      | 15.09       |
| By Furniture and Fixtures .....         | 311.19      | 100.10      |
| By Scientific Apparatus and Specimens   | .80         | 797.55      |
| By Live Stock .....                     | 24.30       | 259.00      |
| By Traveling Expenses .....             | 218.31      | 334.07      |
| By Contingent Expenses .....            | 20.00       |             |
| By Buildings and Land .....             | 511.01      | 76.29       |

|             |             |             |
|-------------|-------------|-------------|
| Total ..... | \$15,000.00 | \$15,000.00 |
|-------------|-------------|-------------|

Respectfully,

(Signed): M. A. GLENN,

Treasurer.

State of Alabama:

Lee County.

Personally appeared before me, B. L. Shi, a Notary Public in and for said county, M. A. Glenn, known to me as Treasurer of the Alabama Polytechnic Institute, who, being duly sworn, deposes and says the above foregoing account is true and correct. Witness my hand this 29th day of January, 1918.

B. L. SHI,

Notary Public, Lee County.

This is to certify that I have compared the account with the ledger account of the Treasurer, and this is a correct transcript of the same.

CHAS. C. THACH

President Alabama Polytechnic Institute.



# REPORT OF DIRECTOR AND AGRICULTURIST

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J. F. DUGGAR

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Auburn, Ala., January 28, 1918.

Dr. C. C. Thach, President,  
Alabama Polytechnic Institute,  
Auburn, Ala.

Sir:

I respectfully submit the following report for the past year of the work under my charge as Director and Agriculturist of the Alabama Experiment Station:

## PUBLICATIONS

The publications of the Alabama Experiment Station for the fiscal year ending June 30, 1917, consist of the annual report, five bulletins, two circulars and five press bulletins, making a total of thirteen publications. Below I give their titles and authors:

Bulletin No. 192: "Cottonseed Meal Compared with Velvet Beans for Fattening Steers;" by the Animal Husbandman and Assistant.

Bulletin No. 193: "Peanuts; Tests of Varieties and Fertilizers;" by the Director and Assistants.

Bulletin No. 194: "Growing Peanuts in Alabama;" by the Director and Assistants.

Bulletin No. 195: "The Cause of the Disappearance of Cumarin, Vanillin, Pyridine and Quinoline in the Soil;" by the Botanist.

Bulletin No. 196: "The Nitrification of Pyridine, Quinoline, Guanidine, Carbonate, etc., in Soils;" by the Associate Agriculturist.

Circular No. 35: "Annual Report of the Director of the Experiment Station on Work Done Under the Local Experiment Law in 1916." (From the Local Experiment Fund.)

Circular No. 36: "Preserving Eggs for Home Use;" by the Animal Husbandman. (From the Local Experiment Fund.)

Press Bulletin No. 85: "Separation of Corn Cockle Seed from Commercial Narrow Leaf Vetch Seed;" by the Assistant in Agriculture.

Press Bulletin No. 86: "Tests of Varieties of Corn in 1916;" by the Associate Agriculturist.

Press Bulletin No. 87: "Varieties of Fruit for the Home Orchard in Alabama;" by the Associate Horticulturist and Field Agent in Horticulture. (From the Local Experiment Fund.)

Press Bulletin No. 88: "Tests of Varieties of Cotton in 1916;" by the Associate Agriculturist.

Press Bulletin No. 89: "The Home Orchard; Setting and Care;" by the Associate Horticulturist and Field Agent in Horticulture. (From the Local Experiment Fund.)

Bulletin Index for Volume 22. (1914.)

Bulletin Index for Volume 23. (1915.)

Between July 1st and December 31, 1917, there were also published the following:

Bulletin No. 197: "Harvesting and Storing Sweet Potatoes;" by the Associate Horticulturist.

Bulletin No. 198: "Velvet Beans Compared with Cottonseed Meal for Fattening Steers. Velvet Beans, Cottonseed Meal and Corn as Feeds for Dairy Cattle. Velvet Bean Pasture Compared with Corn and Dried Blood; Velvet Bean Meal Compared with Corn for Fattening Hogs;" by the Animal Husbandman and Assistants. (From the Local Experiment Fund.)

Press Bulletin No. 90: "How to Save Alabama's Corn Crop;" by the Entomologist.

Press Bulletin No. 91: "Tests of Varieties of Corn in 1917;" by the Associate Agriculturist.

Press Bulletin No. 92: "Tests of Varieties of Cotton in 1917;" by the Associate Agriculturist.

(Reprint) Press Bulletin No. 67: "Oat Smut;" by the Director and Agriculturist. (From the Local Experiment Fund.)

This shows that the publications for the calendar year 1917 have been six bulletins, two circulars, three press bulletins and a reprint of one press bulletin, making a total of twelve publications. These show that a total of 236,500 separate copies have been distributed. These contained a total of 2,748,000 pages in all editions.



## STAFF

Professor Ernest Walker resigned as Horticulturist September 1, 1916, in order to enter on private horticultural work. He had devoted three years of intense application to his duties as Professor of Horticulture, Horticulturist of the Experiment Station, and to the trying duties of State Horticulturist. The growth and progress of the latter work during this period is a monument to his industry and zeal. His death occurred shortly afterward.

On January 1st, 1917, Professor G. C. Starcher entered on his duties as Horticulturist. P. O. Davis resigned as Assistant in Horticulture March 15, 1917, and was succeeded by Otto Brown who left the employment of the Station soon after the close of the fiscal year.

In September, 1917, Dr. Wright A. Gardner became Botanist of the Experiment Station, succeeding Dr. W. J. Robbins, who resigned to enter commercial work.

During the past fiscal year the Experiment Station suffered the loss by death of Dr. J. T. Anderson. For many years he had been Chemist of the Station devoting special attention to soils and crops. Near the close of the last fiscal year O. L. Howell and F. E. Boyd resigned as Assistants in Agriculture. The duties formerly discharged by them were rearranged and assumed by H. B. Tisdale as Associate Plant Breeder, whose connection with the Station had been interrupted by a year's leave of absence for graduate study in Cornell University.

## REPORTS OF DEPARTMENTS

On the following pages appear the reports of the Botanist, the Horticulturist, the Plant Pathologist, the Animal Husbandman, the Physiological Chemist, and the Veterinarian, which record the nature of the experimental work in their respective departments.

## AGRICULTURAL DEPARTMENT

Auburn, Ala., January 30, 1918.

(Work under Hatch and Adams Funds.)

The field work has been conducted by the Associate Agriculturist, E. F. Cauthen.

Plant breeding continues to be one of the lines of work that occupies much of the time of the members of this Department.

The large amount of data accumulated on correlations between yield and various qualities of the corn plant and corn ear have been to a large extent summarized and put in shape for publication.

The breeding of oats has been continued and field tests indicate its practical value. It is hoped that at an early date there may be prepared for publication a part of the data accumulated by a number of years' breeding of cotton and oats. Field tests both at Auburn and other parts of the State continue to give increasing evidence of the value of the strains of cotton, corn, and oats evolved as a result of the breeding work at Auburn.

It is believed also that the results when fully analyzed will throw important light on some of the details of plant breeding that are important from a scientific standpoint.

The following is a list of the principal field experiments conducted on the Station farm in 1917:

Alfalfa, fertilizer, variety and culture experiments.

Barley, variety tests.

Cotton, effects of planting light and heavy seed.

Cotton, variety tests of short staple and long staple.

Cotton, breeding with Cook and hybrids.

Cotton, culture experiments, including thick and thin plantings and subsoiling.

Cotton, time of applying nitrate of soda.

Corn, variety tests, early and late plantings.

Corn, Williamson versus other methods of culture.

Corn, methods of planting velvet beans in.

Corn, best rotation for.

Cowpeas, variety and culture tests.

Cowpeas, for soil improvement.

Cowpeas, rate of seeding for hay.

Crops, residual effects of different kinds.

Clovers, tests of species and varieties.

Clovers, best plants for sowing with legumes.

Grains, as forage crops.

Forage crops, tests of many species and varieties.

Grasses, tests of species and varieties.

Hog crops, chufas, peanuts, soy beans, etc.

Hemp.

Kudzu for hay and for smothering nut grass.  
 Lime, effects of lime as a fertilizer on different crops.  
 Nitrogen, different kinds of meal as a source of.  
 Oats, variety tests, methods of seeding, and time of sowing.  
 Oats, breeding experiments.  
 Oats, fall sown versus spring strains.  
 Phosphates, raw versus acid, versus basic.  
 Peanuts, variety tests, early and late plantings.  
 Peanuts, rate of seeding and spacing.  
 Peanuts, shelled versus not shelled for planting.  
 Peanuts, different kinds of fertilizers for.  
 Rotation experiments.  
 Rye, variety tests.  
 Silage, yield of different crops for.  
 Soybean and cowpea mixtures for hay.  
 Soybeans, tests of varieties for seed, for hay, and for oil.  
 Soybeans, rate of seeding.  
 Sorghum, tests of varieties for forage and for syrup.  
 Subsoiling, for corn, cotton, cowpeas, and alfalfa.  
 Sudan grass, alone and with legumes.  
 Sugar Cane, Japanese, as a forage crop and for syrup.  
 Velvet Beans, varieties for seed and for hay.  
 Vetches, varieties.  
 Vetches, best mixtures.  
 Wheat, breeding experiments.  
 Wheat, varieties.

#### DIVISION OF SOILS

In this division Prof. M. J. Funchess has secured results from his laboratory and field experiments that promise great practical as well as scientific value.

A continuation of the experiments to determine the lasting effect of certain organic toxins indicates that most compounds lose their toxicity after being in contact with soil for a time.

At this date, there is no indication of a toxic effect of vanillin, cumarin, or quinoline added in July, 1917, to the soil from the Arlington farm.

The work on the development of soluble manganese in acid soils is yielding very interesting results. It has been very clearly shown that nitrification of dried blood may bring into solution relatively large amounts of manganese. Further, it

has been shown that it is not necessary for added sulfate of ammonia to be nitrified to cause an increase in the amount of this element in solution. Soil extracts which are toxic because of soluble manganese have been made productive by the additions of either calcium, sodium, or potassium hydroxides. For the growth of garden peas, the addition of pure calcium carbonate to such extracts markedly reduces the toxicity. The addition of lime to an acid soil prevents completely the solution of manganese.

A manuscript relative to manganese for publication is nearing completion.

Respectfully submitted,

J. F. DUGGAR,  
Director and Agriculturist.

## REPORT OF BOTANIST

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WRIGHT A. GARDNER

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Auburn, Ala., January 15, 1918.

Prof. J. F. Duggar,  
Alabama Experiment Station,  
Auburn, Ala.

Sir:

Having taken charge of this department September 1, 1917, I make a report from notes left by my predecessor, Dr. William J. Robbins.

(1.) Under the Soils Toxin Project, which is carried on under the Adams Fund, Bulletin 195, The Cause of the Disappearance of Cumarin, Vanillin, Pyridine and Quinoline in the Soil, was published in June, 1917. An investigation has been made which shows that bacteria decompose vanillin. Studies are in progress to show the effect of the addition of vanillin on the bacteria flora of soil, and on the conditions determining the digestion of vanillin.

(2.) No projects have been definitely outlined under Hatch funds. Some work has been done on each of the following:

1st. Control of nematodes by the application of formaldehyde and carbon bisulphide.

2nd. The effect of aluminum nitrate on the root growth of red clover and sorrel.

3rd. The effect of certain factors on the digestion of cellulose by *Penicillium* species.

(3.) The list of Station projects are:

1st. Soil Toxin Projects, Adams Fund.

2nd. Miscellaneous Botanical Investigations, Hatch Fund.

Respectfully submitted,

WRIGHT A. GARDNER,

Botanist.



## REPORT OF PLANT PATHOLOGIST

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G. L. PELTIER

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Auburn, Ala., October 25, 1917.

Prof. J. F. Duggar, Director,  
Agricultural Experiment Station,  
Auburn, Alabama.

Sir:

I am herewith submitting a brief statement relative to the projects now in progress in the Department of Plant Pathology for the past year.

1. Under the Adams Fund only one project, Citrus Canker, is being carried on. The citrus canker organism has been isolated directly from the soil and a method is being developed by which this can be done with ease and consistency. One of the most important factors to be determined is to find out how long the organism causing the Citrus Canker can persist in the soil, after the infected trees are destroyed, so that the development of a successful method for the isolation of the organism from the soil is of the utmost importance.

Through an agreement with Dr. W. T. Swingle, of the Bureau of Plant Industry, a series of plants representing the more important wild relatives and species of Citrus, together with the more common species and hybrids, have been obtained and placed in the field at Loxley and in the greenhouse at Auburn, for use in determining the relative susceptibility and resistance. These plants have been inoculated with virulent strains of canker and already some of them give promise of immunity. If resistant, they can replace the more susceptible Citrus plants in the orchards now destroyed and also replace the plants now in use as stock in South Alabama. A number of other important phases in the life history of Citrus canker organism are also under way.

During the summer a well equipped field laboratory was maintained for the study of Citrus Canker at Loxley, in charge of Mr. D. C. Neal, formerly a fellow at the Missouri Botanical Garden. Through an agreement with Dr. K. F. Kellerman, Mr. Neal will continue the work at Loxley during the coming year.

2. Several projects are now in progress under the Local Experiment Fund, including a study of the roots of dasheen both in the field and in storage, a new disease of the pecan, Japanese persimmon, and cherry, plum and peach.

Five fungi causing a rotting of dasheen in storage have been studied in the laboratory. In an experiment now in progress, an attempt was made to determine what fungi causing rots in storage would develop in the field from the use of diseased corms. To date, all results have been negative, showing that **these fungi, while they are very destructive in storage, do not seriously affect the germination of the corm and are unable to attack the growing plants.**

A *Diplodia* and *Botryospharia* have been isolated from diseased material of pecan and other hosts mentioned above. Many field observations were made during the course of the year. Some inoculation work has been attempted in the greenhouse and field at Auburn. A study of these troubles will be continued.

Field and laboratory observations have also been made on the anthracnose of cereals, *Physoderma* disease of corn, peanut yellows, and several spot diseases of the legumes.

### 3. List of projects:

Adams Fund—Citrus Canker.

Local Experiment Fund—Storage and Field Rots of the Dasheen. Wilt and Die Back of Pecan, Japanese Persimmon, Plum, Cherry and Peach. Miscellaneous Phytopathological investigations.

4. The Department of Plant Pathology is cooperating to some extent with Dr. W. T. Swingle, of the office of Crop Physiology and Breeding Investigations, Bureau of Plant Industry, Dr. K. F. Kellerman, Associate Chief of the Bureau of Plant Industry, and Dr. E. C. Stakman, of the office of Cereal Investigations and Minnesota Agricultural Experiment Station. All three of these agreements are of recent date so that no results have been obtained as yet.

Respectfully submitted,

GEO. L. PELTIER,

Plant Pathologist.

## REPORT OF HORTICULTURIST

G. C. STARCHER

Auburn, Ala., October 31, 1917.

Prof. J. F. Duggar,  
Director of Experiment Station,  
Auburn, Ala.

Sir:

In response to your request, I herewith submit a report on the progress of the work in this Department.

We are completing our work on varieties of apples and will be ready for publication as soon as the notes can be compiled.

Persimmons—We have completed our variety notes on persimmons. This data will be ready for publication as soon as it can be compiled.

Peaches—We have continued our variety notes on peaches.

Grapes—We have completed variety tests of grapes and have this data ready for compilation.

Sweet Potatoes—We will complete, with this season, variety notes on sweet potatoes and will have this data ready for publication as soon as it can be compiled.

We completed our first series of experiments on sweet potato storage and have published same.

We have continued certain other experiments on fertilizers and vine cuttings vs. slips, etc. for sweet potatoes.

Sweet Corn—We have completed our variety tests of sweet corn and this data will be ready for publication as soon as it can be compiled.

Tomatoes—Due to disease, our variety notes on tomatoes were a complete failure this year.

Pears—We have abandoned our fertilizer experiments on pears for the prevention of Fire Blight due partially to the fact that potash can no longer be secured and partially to the fact that Fire Blight has practically destroyed the orchard.

Variety tests which have been carried on with pepper, okra, egg plant and cucumbers were abandoned for the present year on account of climatic conditions.

Yours very truly,

G. C. STARCHER,  
Horticulturist.

## REPORT OF ENTOMOLOGIST

W. E. HINDS

Auburn, Ala., November 13, 1917.

Prof. J. F. Duggar, Director,  
Experiment Station,  
Auburn, Ala.

Sir:

Herewith I give you a report of Entomological work in hand.

Adams Projects: 1. Rice Weevil. Continued investigations in field and laboratory, confirming conclusions as to simple, practicable, effective methods of control aside from insecticidal methods. Indications that over half of prospective loss of over \$10,000,000 in present Alabama crop of 80 to 90 million bushels of corn might be saved by general practice of (A) gathering all early maturing corn with husks on within six weeks after it reaches "roasting ear stage" so as to remove practically all of first generation before spread can occur to later maturing corn. Use trap rows or plots to concentrate this first generation. (B) Selecting seed ears from the stalks in the field in the fall, keeping only such as have (a) good, long, tight-fitting husk, (b) of prolific type, (two or more ears per stalk) (c) ears pendent when mature, (d) more careful selection later for grain and all other characters. (C) Harvesting main crop corn as soon as thoroughly mature, breaking ears from the shuck as they are gathered, thus leaving 75 per cent. of adult insects in the field, separating infested from uninfested ears as they are thrown into wagon body and storing separately later. Feed out, fumigate or otherwise dispose of infested corn first. Uninfested ears may be stored in even open pole cribs with good roofs, with little damage. (D) Avoid storing with shuck on and, especially, using salt which increases, instead of decreases, insect damage. (E) Fumigation with carbon disulphide in tight room or bin or barrels for seed corn, cow-peas, wheat, etc. in early storage season—on warm days only.

Results of this project work are applicable throughout cotton belt especially and if generally practiced might easily save corn, etc. worth this year something like \$10,000,000. I consider this now one of the most important subjects for Extension Work in the South.

2. Arsenate of Lead project held in abeyance this year on account of scarcity of peach crop which was the principal subject in use in field work heretofore.

3. Fumigation: Continued investigations. Subject of applicability of Cyanide fumigation to Satsuma Orange insect control under Alabama climatic conditions is now under way.

#### OTHER PROJECTS

1. Boll weevil has now advanced so it occurs in all of Alabama except for a distance of about fifteen miles southwest from the extreme northeastern corner.

2. Argentine ant located at other points in Mobile County.

3. Citrus Insects: Greatly reduced in numbers this year following most severe cold experienced since 1899, except soft brown scale which has been more abundant than ever before and has also proven harder than usual to control. Fumigation investigations will be extended to include this subject.

4. Sweet potato root borer presence in Alabama suspected but quite extensive inquiry and field and shipping shed inspection have failed to give as yet a single positive proof of the presence of this pest in Alabama.

No special results from cooperative work. The death of Dr. J. T. Anderson has delayed our getting reports on some cooperative Arsenate of Lead analytical work.

Respectfully submitted,

W. E. HINDS,  
Entomologist.



## REPORT OF ANIMAL HUSBANDMAN

---

G. S. TEMPLETON

---

Auburn, Ala., October 30, 1917.

Prof. J. F. Duggar, Director,  
Alabama Experiment Station,  
Auburn, Alabama.

Sir:

I respectfully submit the following report for experimental work conducted by the Animal Husbandry Department for the past year.

The experiments conducted at Auburn, Alabama, were supported by the Hatch and Adams Funds appropriated by Congress. The experimental work conducted in Marengo, Mobile and Dale counties was supported by the State appropriation provided by the Local Experiment Law.

### ADAMS PROJECT

A study of the influence of some of the southern feeds on the properties (melting point, iodine value, keeping qualities and color) of lards. This experiment was conducted in co-operation with the Department of Chemistry. Six lots of hogs were fed the following rations:

Lot 1. Five pigs. Corn alone.

Lot 2. Six pigs. Velvet bean meal.

Lot 3. Six pigs. Corn, one-half, velvet bean meal, one-half.

Lot 4. Six pigs. Velvet bean and pod meal.

Lot 5. Six pigs. Peanut meal one-half, corn one-half.

Lot 6. Six pigs. Peanuts one-half and corn one-half.

Samples of kidney fat from each individual in all of the lots were given to the Chemistry Department for laboratory work. The Chemistry Department will make a report on these analyses.

Briefly, the velvet bean meal produced a carcass as firm as the corn fed carcass, but it showed a slightly darker fat than the corn fed carcass.

The lot fed velvet bean and pod meal did not put on sufficient flesh to make the analysis of the lards very satisfactory.

The lot fed one-half peanut meal and one-half corn produced a carcass somewhat softer than the corn carcass, and would be discriminated against by the packer at the rate of about one cent per pound as compared with the corn fed hogs.

The ration of one-half corn and one-half peanuts produced a carcass with an average melting point of 39.5 degrees C, and an iodine value of 81.12. The carcasses in this lot were considerably softer than those fed a ration of one-half peanut meal and one-half corn.

The ration of peanut meal one-half and corn one-half produce a carcass with an average melting point at 39.39 degrees C., and an iodine value of 70.15.

#### HATCH PROJECT

With dairy cows there was made a comparison of velvet bean and pod meal versus cottonseed meal for milk and butter-fat production. The results were published in Bulletin No. 198 of this Station.

With dairy cows an experiment was also made comparing ground velvet beans and pods with soaked beans and pods.

The ground beans and pods gave better gains than the soaked ones. The difference can be explained in part at least by the fact that the ground beans were more palatable and more of them were eaten. The results are presented in the bulletin just mentioned.

Respectfully submitted,

G. S. TEMPLETON,

Animal Husbandman.

## REPORT OF VETERINARIAN

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C. A. CARY

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Auburn, Ala., January 28, 1913.

Prof. J. F. Duggar,

Director, Alabama Experiment Station,

Auburn, Alabama.

Sir:

During 1917 the following lines of work were conducted:

(1.) Attempts were made to determine whether the eggs of the kidney worm (*Strongylus pinguiicola*) passed into the ureters and bladder and out to the ground with the urine. In a number of pigs the eggs were found in the urine in the bladder.

Also the urine infested with eggs was placed under the following tests to determine if the eggs hatched outside of the body in water, soil and urine.

Test 1. A sample of highly egg-infested urine was mixed with 10 c. c. of tap water to which was added one drop of formalin. This was kept at room temperature and examined daily for 17 days. Gradual development of embryos occurred and on the 17th day an embryo 0.42 m. m. in length was found.

Test 2. 5 c. c. of egg-infested urine was added to 10 c. c. of branch water. Daily examination revealed no eggs after the 15th day and on the 17th day embryos were found .4 to .5 m. m. in length.

Test 3. One drop of formalin was added to 15 c. c. of egg infested urine. No eggs present on the 17th day and embryos over .5 m. m. in length were found.

Test 4. 5 c. c. of egg infested urine was added to 10 c. c. of plain tap water. Eggs were found on the 17th day. These eggs showed developing embryos in the egg shell or capsule and there were a few small free embryos.

Test 5. Urine from egg infested bladder was spread over small box of dirt. This was kept moist with tap water and on the 17th day small embryos were found and no eggs.

This seems to prove that eggs of the *Strongylus pinguiicola* will hatch at ordinary temperature in about 17 days in urine, water and moist soil. Also there is no doubt that the eggs pass out with the urine.

In all cases where post mortem examination was made on hogs having paralysis of the hind quarters or limbs we have found the kidney fat worm (*Strongylus pinguicola*) in the kidney fat, the kidney, sublumbar muscles and in one instance in the spinal canal under the dura mater. This does not declare it the actual cause of the paralysis but it may be the real or an associate cause.

The Senior Veterinary Medical students under my direction collected 180 specimens of horse flies of the Tabanidae family, all of which were collected from September 18 to October 20, 1916. This period covers the life of longevity of the adult Tabanidae at Auburn, Ala. The egg laying period has not been determined for this place, but it appears to extend from June until some time in August.

A test of the action of the bitter weed (*Helenium tenuifolium*) on cattle, dogs and horses was made. No distinct effect was apparent in cattle except the bitter taste in milk. In the dog it produced nausea, vomiting and depression of temperature. In the horse in one case it produced dullness, dry mouth, depressed the pulse from 38 to 28, temperature from 100 to 99 and respiration from 11 to 7 and in four hours it produced purgation. The animal remained sluggish for several days thereafter. This horse was fed  $2\frac{1}{2}$  gallons of the plant mixed with  $2\frac{1}{2}$  gallons of oats. Another horse was fed three gallons of the bitter weed and the pulse became weak and slow, respiration retarded, mucous membranes pale, soft feces passed frequently, cold sweat appeared and the horse became sleepy and sluggish. From these and other tests it appears that bitter weed is toxic for horses, mules and dogs but apparently not toxic for cattle.

Another series of tests were made to determine the toxic effects of *Eupatorium ageroides*. Apparently it produces progressive degenerative change in the red blood cells, polymorphonuclear cells, and eosinophiles, and in the cat, dog and goat it failed to produce any symptoms resembling "trembles."

Quite a large number of ovaries from sows and gilts that had been fed peanuts were examined to see if any changes were produced by this feed that might produce sterility. No definite results have been determined.

One Farmers' Leaflet on Infectious Keratitis was issued.

On account of the war disturbing the available men for Institute work during the Summer 1917 few institutes were held. The Farmers' Summer School was held at Auburn, July 29th to August 4th, 1917. The total attendance was 539, and 37 counties and 9 states were represented.

Yours truly,

C. A. CARY,

Veterinarian.



## REPORT OF PHYSIOLOGICAL CHEMIST

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C. L. HARE

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Auburn, Ala., Jan. 29, 1918.

Professor J. F. Duggar, Director,  
Alabama Experiment Station,  
Auburn, Alabama.

Sir:

Work on Adams Fund projects in the Department of Chemistry during the past year has been concerned with determining the effect of peanuts and particularly of velvet beans upon the properties of lard from hogs receiving these rations. This work has been in cooperation with the Department of Animal Husbandry.

Experiments under the Hatch Fund were in part suspended temporarily owing to changes and losses in personnel of the Chemical Staff.

Respectfully submitted,

C. L. HARE.





ALABAMA  
**Agricultural Experiment Station**  
OF THE  
Alabama Polytechnic Institute  
AUBURN

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**Report on Freeze Injury to Citrus Trees for  
1916 and 1917, with Notes on Orange  
Culture in South Alabama**

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By  
O. F. E. WINBERG and G. C. STARCHER  
Assisted by  
C. L. ISBELL

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Opelika, Ala.  
Post Publishing Company,  
1918

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     tural Engineer.



# REPORT ON FREEZE INJURY TO CITRUS TREES FOR 1916 AND 1917, WITH NOTES ON ORANGE CULTURE IN SOUTH ALABAMA

By

O. F. E. WINBERG AND G. C. STARCHER

ASSISTED BY

C. L. ISELL

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## INTRODUCTION

A few citrus trees have been grown in the yards and around the houses in South Alabama for perhaps fifty years or more. Most of these were seedling sweet or sour oranges and a few seedling lemons.

The introduction of the Mandarin Orange, Satsuma variety, the pomelo, or "grape fruit" Nagami and Marumi varieties of kumquats and the tangerine marked the beginning of the citrus industry in South Alabama on a larger or commercial basis.

Since the introduction of these fruits into South Alabama, the development of the citrus industry has been rapid. Present conditions point to the continuation and acceleration of this development. During this short period of development some growers have made mistakes and in consequence thereof suffered losses. The growers are not altogether, or perhaps not at all to blame for these mistakes nor should they feel too strongly the pain of disappointment which they have suffered, because in any new industry there must be pioneers, mistakes and disappointments out of which success will come. Pioneers in the citrus industry in South Alabama have furnished, together with our experiences, material for this bulletin compiled from tabulated freeze reports and individual tree statistics from Baldwin and Mobile Counties on 1360 orchards or parts of orchards containing 446,746 trees.

The killing and banking graphs as well as some of the general conclusions are drawn from about 55,000 summarized words tabulated under the following topics: The number of trees killed and killed back with dates; time, kind and amount of fertilizer; time, kind and amount of cultivation; elevation and depressions; time of banking and its effect; character of soil;

perfection of both air and soil drainage; nearness to and the effect of bodies of water; the position, kind and effect of wind-breaks.

There were so many trees planted, protected, fertilized and cultivated in so many different ways that we found it impossible to make a correct percentage or graph for any of the above topics, except banking, killed and killed back, and these only for the Satsuma and grape fruit. Lemons, sweet, sour and navel oranges were planted in small areas around dwellings, barns, chicken lots, etc. and under such other varied conditions that no accurate graph could be made. The kumquat was also planted around dwellings, barns, chicken lots, etc. for the turn rows and along fences under such different conditions that no graph could be made.

For the collection of the data from which this bulletin is compiled we are indebted to Dr. R. Van Iderstine, John W. Paec, Colin McDonald, T. F. Johnson, Leonard G. Payne, Robert W. Porter, Robert M. Mahler, and their assistants in the Citrus Canker eradication work and the hundreds of growers who so willingly gave the necessary information.

### MAP EXPLANATION

Since the freeze injury reported in this bulletin occurred, it has been the opinion of some of the citrus growers of South Alabama and perhaps is still the general opinion of the casual observer, that trees planted in all hollows and low places suffer much heavier losses from freezes than trees which are on elevated areas. The graphs and maps on pages 7 and 8 are intended to give the growers suggestive corrections for this mistaken idea, especially in a hilly district, whereas in a more level district, swamps may act differently as shown by Plate III and fig. 1 of Plate IV.

Generally speaking, losses from freezes may be heavier in hollows and low areas than on elevated areas. But when these increased losses occur it is generally due to either lack of air drainage or the presence of a wind-break or wind-stop, proximity to a swamp or a combination of these conditions. Cold damp air will settle in low places adjacent to these surroundings. Just so far as this cold damp air extends be it in low or elevated places, those areas will suffer losses in proportion to the dispersement of the cold still damp air. See graph, page 7.

Map No. 1 (page 7) Field No. 1 is a forty-acre plot set to Satsuma oranges. This plot contains two natural drains; one from the north and the other from the west, which unite near the center of the field to form a larger drain which slopes in a southern and south-easterly direction. Above drain No. 2 the wind from the northwest from which direction most cold waves come, has a free sweep for a long distance. As it enters the head of drain No. 2 it forces the cold, damp air out of this drain, draws it from drain No. 1, sweeps down the main drain, carrying the cold, damp air before it to the creek. Not a tree was lost in this forty acres from the freezes, and there are six other draws on the same plantation showing similar results.

Field No. 2 is a forty-acre plot set to oranges. This plot contains one drain which runs across the north-east corner in a south-easterly direction. There is timber along the north side of this drain which forms a wind-break. The cold, damp air on the south side of this drain No. 3 was not dispersed and the trees are killed to the bank as far up as the still cold air extended (indicated by dotted area). Only banking saved part of this orchard. Concluding from results in field No. 1, had the timber been cut from the north side of brook No. 3, no trees would have been killed to the bank in field No. 2.

Field No. 5 is a forty-acre plot set to oranges, except a small area in the north-west corner which is cut off by a highway. This plot contains two natural drains, No. 4 and No. 5, in the north-eastern portion which slope in a north-western direction, and it also has a general western slope toward the creek on the west. Field No. 4 is a forest which serves as a wind-break for field No. 5. Cold, damp air settling in drains Nos. 4 and 5 and near the creek in the north-west corner killed all the trees in these areas. Also a few trees were killed up to the middle of the forty from the west side of the field. But, comparatively few were killed, as some free wind came through the opening at the bridge as indicated by wind arrows sweeping down the western side with enough force to partially disperse the cold damp air.

The dashed line in field No. 5 indicates the top of the hill beyond which no trees were killed. A similar line in field No. 1 indicates an equal elevation below or above which no trees were killed.

The black irregular line around each drain is a suggestive contour line with equal elevation and slope towards the main creek. Notice that all trees were killed below and some above this line in field No. 5, while in field No. 1 not a tree was lost.

Fields Nos. 6, 7 and 8 are shown only for relative positions. Field No. 3 shows the same general result as shown in Map No. 2, Field No. 1.

Map No. 2 (page 8)—This map shows 160 acres set to oranges with the exception of a small area in the south-east corner. The area contains one brook in the north-east section and a creek extends across the south-east corner bordering the south. You will note in field No. 2 of this map that 25 per cent. of the trees along the drain were killed. The woods north, east and south of this drain kept the north wind from dispersing the cold damp air which settled and caused freezing.

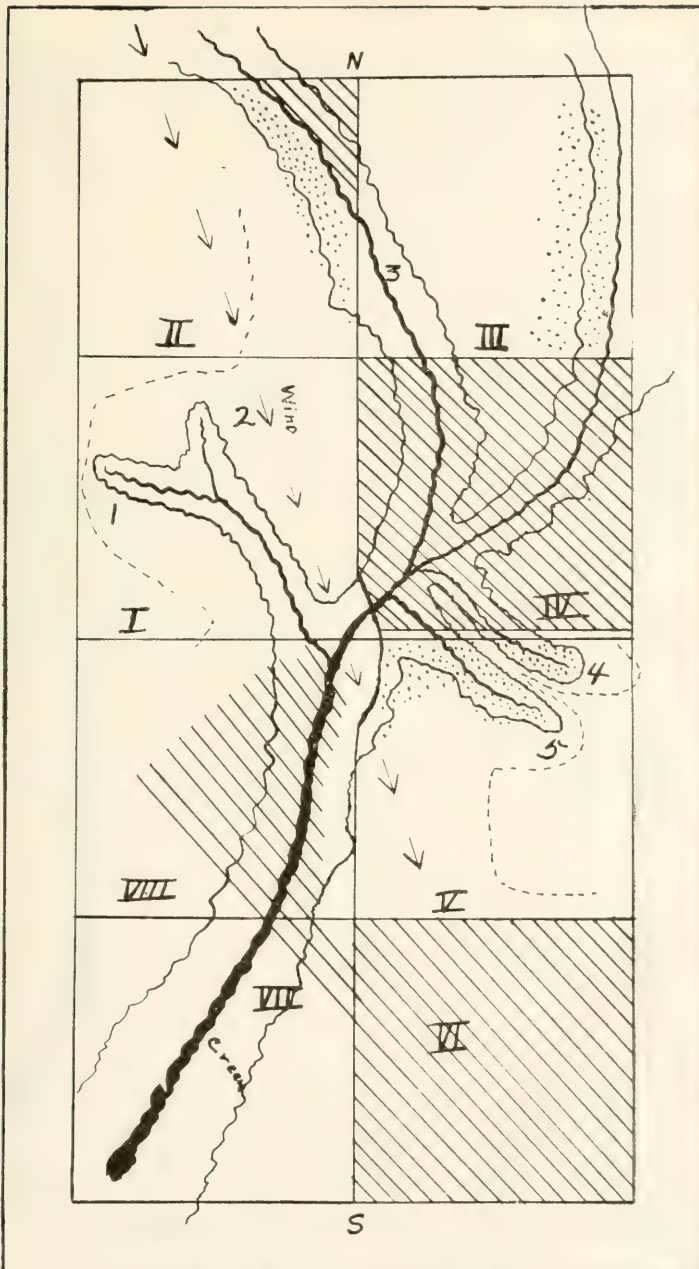
When there is perfect air drainage for the field as a whole, and the field slopes in the direction of wind-flow, the trees will not be killed on the level area and as far down the hill as the circulating air disperses the cold damp air. In case of a gradual slope of about one or one and one-half inches per foot, where the wind current crossing a valley at right angles, or where there is a forest wind-stop at the foot of the hill, the circulating air does not seem to follow down the hill-side, but passes over at the height of the wind stop or the nearest land elevation beyond, thereby permitting the cold, dense air to settle toward the foot of the hill. In a case of this kind described in map No. 2, field No. 1, a greater per cent. of the trees were killed in each succeeding area from the level area to the draw, creek or lowest areas.

Field No. 1 of map No. 2 shows this condition. The wind coming across the level from A to B will not allow the cold, damp air to settle. No trees are killed as the wind passes B to C. The wind is yet near enough to the surface to disturb the cold, damp air and prevent it from settling. No trees are killed. Farther down the hill circulating air does not come near the ground and the killing increases, as shown in the field drawing and graphically to the left of the map. In this instance there was a forest at the foot of the hill and high land just across the valley.

#### ORCHARD SITE

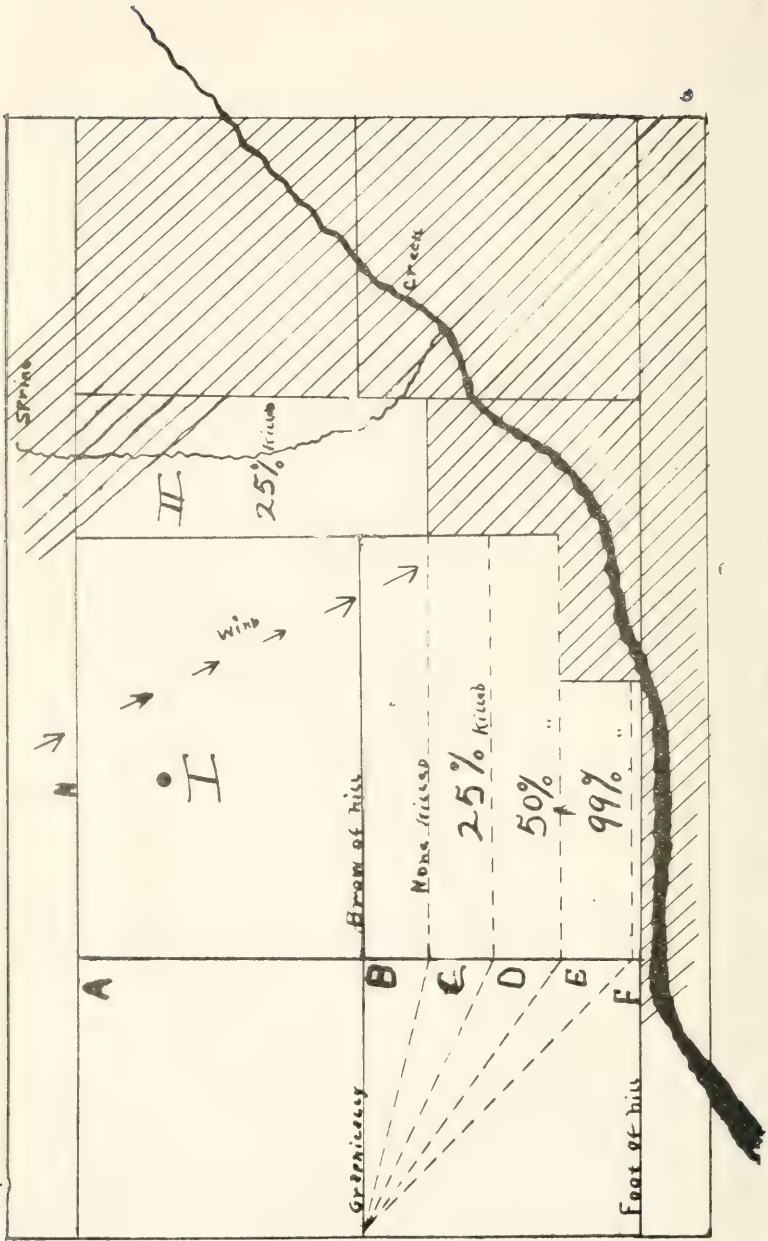
Close observation covering a period of several years in South Alabama relating principally to the selection





Map No. 1. (See page 4.)





Map No. 2. (See page 4.)

of a site for orange groves, including the data summarized in this bulletin, has led to definite conclusions.

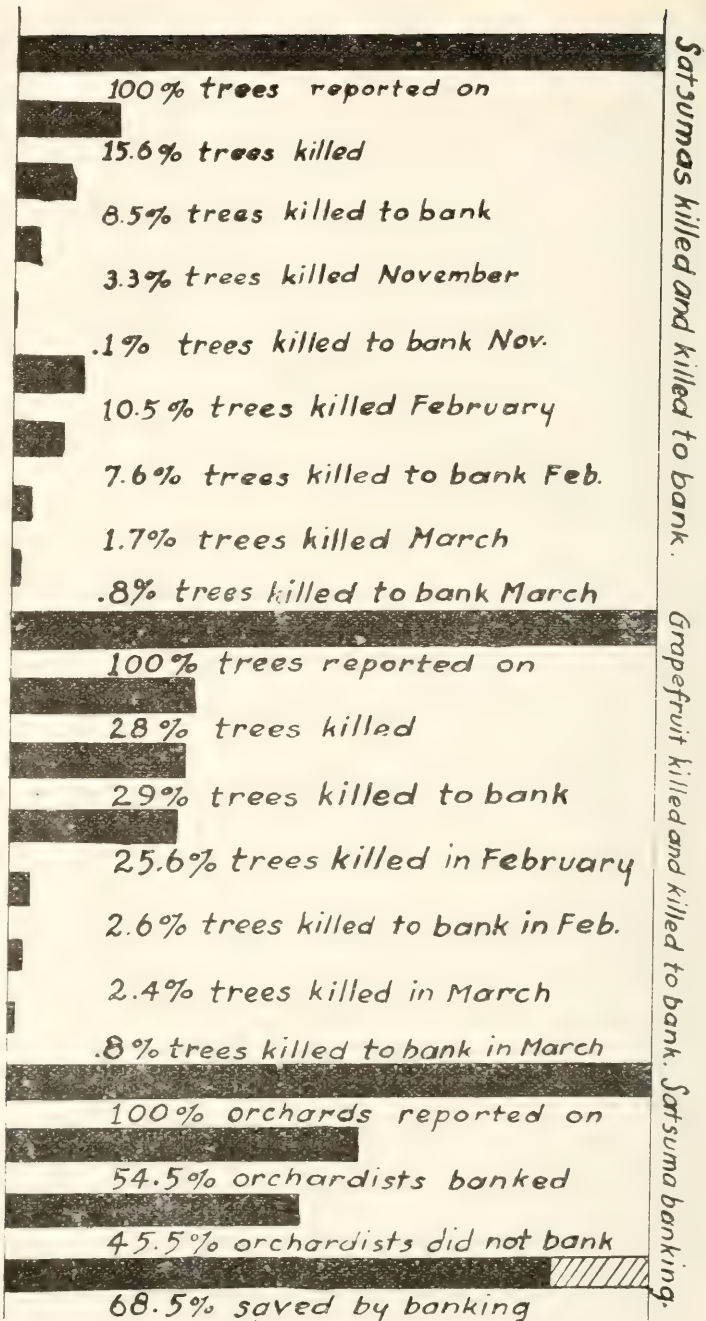
It has been a common error among those not familiar with horticulture to give too little consideration to the selection of a proper site for an orchard except from the point of view of communication, its relative distance from railroad transportation, etc. While these are very important points, they may however be given secondary consideration, because there are other things of more vital importance to be considered.

Some orchardists have believed that an orange grove should not be located on a high elevation where there is no protection against winds from the north-east, north and north-west, but that the best orchard site should have natural barriers against the cold wind. These theories are fundamentally wrong in South Alabama and have been so proved as shown by the maps on pages 7 and 8.

Considering an orange grove as a permanent investment and as an enterprise where considerable capital is involved, it is important that the site be selected on the basis of information contained in this bulletin. This will avoid such losses as many planters suffered in the fall of 1916 and winter and spring of 1917.

The first consideration in selecting the site for an orange grove should be elevation; second, freedom from obstructions on all sides; third, there should be no ponds, swamps or streams adjacent and especially on the north-east, north and north-west sides; fourth, the soil-drainage should be as perfect as possible. If natural drainage does not exist, a tiling system should be provided. However, from the point of frost injury, air drainage is really more important than soil drainage. If there exist natural obstacles, the orange grove will suffer not only a temporary set-back by a freeze, but if the temperature is low enough, the trees may be killed. Where there is a steep southern slope and where the composition of the soil is a light sandy loam the trees will readily respond to warm weather and only a few days are necessary for the trees to begin a vigorous growth. A subsequent low temperature will do considerable injury to such trees and when the temperature is fifteen above zero or less, the trees may not only be set back for a season but may be killed. It is evident that on comparatively level ground where the composition of the soil is rather heavy loam, the trees will not respond to warm weather as quickly and con-

Freeze-Injury Graph. (See page 13.)



sequently low temperature will not have such an injurious effect, unless two or three weeks of warm weather has prevailed followed by a drop in temperature.

Under no consideration should an orchard be located where a small water course, pond or swamp is found in the immediate proximity on the north-east, north or north-west sides because the cold air that is formed in these places under low temperature, instead of being dispersed by the wind will lodge over the surface of the ground in the orchard and cause severe injury to the trees, and if they are not entirely dormant it will kill them. This applies also where the water course is located on the south side and where the slope is rather long and steep. The wind will disperse the cold air from the surface of the ground on the northern part of the slope, but will not do so on the southern part and consequently the trees growing on the lower south side of such slope will suffer from the cold damp air coming off the water course, pond or swamp. It must be remembered that it is not the cold wind that kills the tree, but the cold, damp air that creeps over the surface of the ground and settles. See graph-maps pages 7 and 8.

The future planter of an orange grove should bear the foregoing in mind and select the site for his orchard so that he has as perfect air drainage as possible; that the composition of the soil is not too light; that the slope towards the south is moderate; not over one inch per foot if there is high land across the valley. If the foregoing is followed there will be less frost damage in the future than in the past.

The reason for the greater part of the damage sustained in November, 1916, and February and March, 1917, was in each case due to the fact that prior to such low temperature the weather was warm and the trees had begun to grow. The sudden drop of temperature under conditions described in graphs on pages 7 and 8 was mainly responsible. If the trees had been dormant prior to the low temperature, there would have been no damage.

On the 15th of November, 1916, the temperature was high, the thermometer registering about 80 degrees above zero; on the morning of the 16th the temperature had dropped down to 27 degrees above zero. This sudden drop was responsible for the serious losses sustained at that time, both to the small as well as to the larger trees.



Prior to the low temperature in February, 1917, warm weather prevailed for sometime and the trees were in a sappy condition at the time of the low temperature (15 degrees above zero). From the effects of the low temperature the trees were completely defoliated except in a few instances where the trees were very vigorous because of proper cultivation and fertilization.

Prior to the low temperature (March 5, 1917) the warm weather had caused the trees to put forth a vigorous growth. This, together with the devitalization, caused by the November and February injuries, was mainly responsible for the losses at this particular time.

Defoliation took place practically everywhere, but killing occurred only on improper sites as described in the foregoing paragraphs and where improper cultivation and fertilization had been practiced the previous season.

According to the Government Local Weather Station at Bay Minette, Ala., the lowest temperature during the month of November, 1916, occurred on the 16th, the thermometer showing 27 degrees above zero. On February 3rd, 1917, the thermometer showed 15 degrees above zero and on March 5th, 1917, it showed 26 degrees above.

During the month of December, 1917, the temperature went down to 17 degrees above zero. This low temperature however caused no damage to the orange trees in Alabama because comparatively cold weather had prevailed for at least two weeks prior to this low temperature, causing the trees to become thoroughly dormant. In some orchards we find partial defoliation as a result of this low temperature; in others no defoliation is noticeable. This difference is due to cultivation and fertilization. The orchards well cultivated and fertilized being more vigorous showed no effect from the cold whatever. (See comparative photographs on Plates I and III.)



## FREEZE PROTECTION BY BANKING

The only protection we are acquainted with in this State is BANKING (see Plate VII, fig. 1), that is, hilling up dirt around the tree as high at least as twelve inches from the ground. This is done for the purpose of protecting the bud and should there be any freeze damage it may be possible to save some part of the tree above the bud from which a new tree will develop in a comparatively short time. This banking, in order to be effective, should be done between the 1st and 15th of November.

Fifty-four and one-half per cent. of the growers did not practice banking. Forty-five and one-half per cent. practiced banking to a greater or less extent and reported that sixty-eight and one-half per cent. of the trees which otherwise would have been damaged were saved. See graph on page 10.

## THE EFFECT OF LOW TEMPERATURE ON THE FRUIT

The grower should bear in mind that nearly every year we have a cold spell in the middle or latter part of November, the temperature going down to 28 and some times as low as 25 degrees above zero. Every effort should be made to have the fruit harvested before that time. The Satsuma in the green state will suffer when the temperature goes down to 29 degrees above zero and it thus becomes unsuited for consumption. If the temperature goes below 27 degrees the ripe fruit will be damaged.

The effect of low temperature above referred to is not immediate. A week or ten days will elapse from the time of low temperature till the effect is noticeable. Evaporation follows and the fruit becomes soft and spongy and one or more segments dry up. For example, if an orange is cut open two weeks after it has suffered from above low temperature one or two segments may be dry and the balance beginning to decay, although the outside appearance would be normal except that it is soft. If fruit in this condition is wrapped in tissue paper and packed in the usual manner and shipped to a market requiring four or five days in transit, it is unfit for human consumption when it arrives at destination.

In order to prevent the first fruit being frozen, the grower should in the first place have his orchard in a good state of cultivation in the previous fall; apply the fertilizer early in the spring and cultivate frequently through the summer as described in paragraph on cultivation. If this method be pursued the fruit will reach maturity early in the fall and it will be possible to have it harvested before any serious damage from cold weather occurs.

The fruit of the kumquat will stand a lower temperature than the Satsuma. The green fruit will suffer at 24 above zero, while the ripe fruit will become soft from the effect of low temperature (22 above) but in from ten days to two weeks may again be normal.

### CULTIVATION

The cultivation of an orchard is of the utmost importance. While it has formerly been held that cultivation should begin in the spring and extend over a period of three to four months after which time the orchard should be left alone, our data proved that this system is wrong and cannot be recommended to those engaged in orange culture nor to the prospective grower in South Alabama.

There are several reasons: Aeration is absolutely necessary for the plant to assimilate plant food. Again, the vigor instilled into the plant during the first part of the summer when proper cultivation was maintained is seriously reduced by ceasing cultivation the latter part of July or the first of August. Furthermore, it is evident that the plant cannot avail itself of and assimilate nourishment to the fullest extent when a hard crust is formed on the surface. Moreover the question resolves itself into one of economy as to whether the plant food in the form of fertilizer should be consumed by weeds or by the trees for which purpose it was applied.

Aside from the foregoing the lack of cultivation in the latter part of the season has a very serious effect on the trees and considerably reduces their resistance against cold. The weeds growing in the orchards around the trees retain moisture and consequently the low temperature will more seriously affect such orchards than where clean cultivation is practiced. We would not advise any orchardist now engaged in orange culture nor any prospective grower to follow the

system of non-cultivation during the latter part of the growing season.

The orchard should be cultivated from spring up to as late as October 1st. Where it is necessary to plant legumes between the trees in order to get nitrogen as well as humus into the soil, they should be planted as late as possible in the season, say in the middle of July, and space left on either side of the tree rows sufficient for cultivation.

In cultivating an orchard properly it is very important that suitable implements be used. The plow should not be used in an orchard except in the fall when it is desirable to turn under cowpeas, velvet beans or grass grown for the purpose of increasing the humus in the soil. When the plow is used care should be taken not to plow too deep in an old orchard; in fact, after the trees are three years old the plow should not go deeper than three or four inches.

Small feeding roots extend from five to ten feet from the tree and if plowing is more than four inches deep the feeding roots are cut off and the normal development of the tree is seriously interfered with. This is often the cause of the fruit dropping in the spring as the feeding roots have been cut off and the tree has not sufficient strength to produce fruit and new growth at the same time.

A disc-harrow is a very desirable implement to use in an orchard. This implement should be used alternately with a spring tooth harrow. For example, if an orchard is cultivated one week with the disc-harrow, a spring-tooth harrow should be used the following week going in the opposite direction. By this method it is possible to keep the weeds under control and likewise keep the orchard in a good state of cultivation. The disc-harrow should be the so-called extension harrow so that one side can be extended to go under the limbs of the tree and as near the trunk as possible in order to eliminate hoeing. Another good implement is the so-called California orchard plow or extension disc-harrow, the discs being twelve inches in diameter, making it possible to cultivate under the low-growing branches of the Satsuma orange trees.

The system of hoeing as employed in many orchards, both large and small, from two to three times in a season for the purpose of keeping the weeds away from the trees, is entirely inadequate and should not be depended upon. We recommend complete, clean cul-

tivation in order that the trees may receive the full benefit of the fertilizer applied. It does not receive this benefit when hoeing alone is practiced.

Modern machinery should be used. This is not only because of the labor situation at present, but because of the more efficient way in which cultivation can be carried on. We refer now most particularly to the use of a tractor in the orchard. It is more economical than horse power and does more satisfactory work. (See photograph of tractor at work, Plate VI, fig. 2.)

### FERTILIZATION

Fertilizer should be applied in the orchard early in the season, say January or February. The amount to be applied should be governed by the size and age of the trees. The quality of the soil should also be considered. Where legumes have been planted the previous season the amount of nitrogen should be considerably reduced. For example, if a fertilizer containing three per cent. of nitrogen is applied in an orchard where legumes have not been previously grown, the per cent. of nitrogen can be reduced where legumes have been grown the previous season to one per cent. instead of three.

The reason for the early application of fertilizer is that the fertilizer material used should have time to become available for assimilation by the time the tree begins to grow in the spring. This is particularly important in a bearing orchard as the trees will need considerable plant food at the time of setting fruit. It must be remembered that in order for the tree to have the full benefit of the fertilizer applied, there must be humus present and in order to have this necessary factor in the soil, legumes should be planted as often as may be necessary without getting an excess of nitrogen into the ground.

In years past when potash was obtainable at moderate prices it was persistently advocated that from eight to twelve per cent. of potash should be applied to orange trees. The present shortage of this material has proved that equally as good fruit and as large crops can be grown with four to five per cent. as formerly with from eight to twelve per cent. In fact, during the last two years, potash has been reduced in the fertilizer formulas used in orange groves to even less than four per cent. but the quality of the fruit has



been equally as good as before. However, it would not be a sound policy to advocate the continuation of so low a percentage as above stated when the material can be obtained at the same reasonable figure as formerly prevailed. Therefore, when potash again becomes obtainable on the market at from forty to fifty dollars per ton we advise the following formula: 10 per cent. Phosphoric Acid, 3 per cent nitrogen, and 6 per cent. potash. The potash to be derived from Sulphate of Potassium; the nitrogen from sulphate of ammonia, nitrate of soda or dried blood. As has been pointed out above, legumes should be grown in the orchard not only as a cheap source of nitrogen, but also to increase the humus in the soil, and when this system is practiced, the grower should be guided by conditions in his orchard and reduce the per cent. of nitrogen in his fertilizer from three to two and down to one per cent.

Fertilizer experiments in orange groves in recent years with late applications of nitrate of soda (August 1st) have proved very beneficial. The reason for a late application in bearing orchards is as follows: The nitrogen derived from legumes planted the previous season or from nitrogenous fertilizer applied in the spring, will be largely exhausted before the fruit reaches maturity. The result is that the fruit becomes rather stunted, small in size and the sugar content below normal, although a sufficient supply of potassium may be present.

From an economic and commercial point of view, it should be our aim to improve our fruit in quality and size to conform with the demand of the northern and eastern markets which in the future as in the past will be the principal consumers. Many orchardists believe that the small fruit has a thinner skin and a finer texture and therefore suits their taste better. While this may be true, we are not growing fruit mainly for our own consumption but for the distant markets and the taste of the consumer should be considered.

Since the Satsuma orange growers first began to ship fruit to the northern market in 1914, it has been brought home to them each year that the sizes 120, 144 and 168 per box sell at from thirty to fifty per cent. higher than the sizes 192, 216 and 240 per box. Now there is no reason why the orchardist should not be willing to use every effort to make a tree produce two



boxes of the sizes first named and get as much as fifty per cent. more than to produce two boxes of the smaller sizes.

From practical experiments and careful observation covering a number of years, we have reached the conclusion that it will be possible to grow larger sized fruit without injuring the quality.

### PRUNING

The Satsuma orange tree is naturally a dwarf and must be treated as such. High heading should not be practiced as it results in the ends of the branches turning and growing toward the ground. When these branches become older and heavily laden with fruit they will be drawn nearer the ground, the fruit injured and the branches split under the strain of hard rains, winds and storms which we sometimes have near the coast.

The Satsuma naturally puts out branches on the inner parts of the tree in more or less upright bunches, several of which come close together. Often cross branches appear. As the outer upright branches become older they tend to grow away from the center of the tree and the ends may, and perhaps will, later push outward and downward toward the ground. There are usually some small upright branches on the leaders. In this case a careful pruner will take off the end of the leader, thereby throwing the growing material to the smaller upright branches making them strong and tending to keep the tree in a bunchy, stiff, upright mass which is desirable. Even if the outward down tending end of a branch does not show the presence of a smaller upward tending branch, it is better to cut it off, because there is almost sure to be either a dormant or an adventitious bud which will show up and serve the same purpose as the small upward branch. (See Plate V, figs. 1 and 2 and Plate VI, fig. 1 for careful and careless pruning.)

We do not have much practical experience with cross branches and their value as braces during heavy winds and rains because most of the orange trees in South Alabama are young. Such cross branches, in addition to acting as an ordinary brace, often form natural cross grafts which literally tie the main branches into one, as shown in Plate IV, fig. 2. Of course, some times a cross branch may be ill formed and cause rubbing injury to other branches. In cases of this kind, they should be removed at once.

Branches which have been broken during storms and cultivation should be immediately removed. A very serious mistake in pruning, "or not pruning," is the failure to remove dead wood caused from freezes, storms, etc. Many growers believe this dead wood will not effect the tree in any way if left. It is sometimes left until some convenient time when there is no other work to be done. We believe when the growers learn the following facts, they will not again make this mistake.

When trees are partially killed by freezing, if the frozen branches are pruned off as soon as the extent of killing can be determined, new vigorous branches will put out near the cut and thus in a measure save the former desirable shape and vigor of the tree. If the dead branches are left, new branches may sprout out just below the extent of the killed area. These branches will however be inclined to be weak and will either die soon or dwindle along and die later, or if they live will be stunted and susceptible to future fungus and insect attacks. If the dead wood is left, new sprouts may not put out near the lower area of the freeze injury. In this case the tree will put out numerous branches in the crotch near where the tree was headed resulting in a deformed tree consisting of a mass of sprouts.

Practical observations and experiments on the part of the writers show that orchards pruned as soon after freezing as the injury can be determined will give a vigorous growth; those pruned later will give fair results; and those neglected will give poor results. (See photograph on Plate II for dead wood which has not been pruned out.)

After young trees are transplanted from the nursery to the field, the top often dies back for a few or several inches. This dying back may be caused by either freezes or weakened condition from transplanting. It is highly important that this dried portion be pruned off as early in the spring as its extent can be determined. If it is not taken off an insect often enters the dead branch, makes its way into the heart and begins eating downward. It does not stop its downward movement when the live tissue is reached, but continues until it has eaten the heart out of the tree where the bud was inserted and the tree is destroyed.

In the spring of 1917, some growers were late getting the young trees pruned. Many died back from the effects of the freezes resulting in serious setbacks from insect injury. Even though young trees do not show much dying back, it is well to cut them back the second year if they show a tendency to head too high. This will encourage several branches to put out from near one point which will give a more desirably shaped tree, and one in which natural grafts are more likely to appear.

When *Citrus trifoliata* stock is used, more or less *Citrus trifoliata* sprouts will continue to come until the trees grow older. The number of such sprouts is largely determined by the pruning methods practiced. If the pruner leaves stubs, each stub will put out a number of shoots which will increase the number each year. But if the sprouts are cut close up to the stock with a smooth pruning instrument, they will soon cease to appear. The *Citrus trifoliata* sprout is a rapid grower and that means a heavy feeder as well. The sprouts sometimes reaching four to ten feet and one-quarter to three-quarters of an inch in diameter in a single year. Three or four sprouts may appear. It is, therefore, important to prevent these useless sprouts from receiving plant food which the orange tree should receive.

## VARIETIES

Since the beginning of citrus fruit culture in the Gulf Coast section of Alabama, the question is often asked, "Why confine ourselves to growing Satsumas when we can grow other varieties of citrus fruits?" We take this opportunity to answer this question. There is no citrus fruit better adapted to our climate and soil conditions than the Satsuma. For this reason, we should confine ourselves to this particular variety and use every effort to improve its quality, thereby establishing this fruit on the market, rather than to divide our efforts with probably a minimum of success in growing a number of varieties.

The Washington Navel orange has been planted by a number of growers in South Alabama with fairly good success and it must be admitted that the quality of the fruit is equally as good as the California Navel. We find that the Washington Navel survived the low temperature in the winter of 1917 just as well as the Satsuma. However, we have made this observation,

that while the Satsuma orange trees survived and recuperated sufficiently to bear a crop, the Washington Navel orange, on account of its coming into blossom as early as the latter part of February under conditions like the winter of 1917 when the temperature went down rather low, it is evident that these trees cannot bear a crop. In fact, we have found that if the Navel orange produces a crop every third year, it is all we can expect. Therefore, as a commercial proposition, this fruit should not be considered in this section.

The tangerine, when grafted on *Citrus trifoliata*, is equally as hardy as the satsuma. It comes into blossom about the same time. It is a regular bearer. The quality of the fruit produced in this section is equally as good as that produced elsewhere. But it is a known fact among the orchardists of South Alabama and the consumers in the North and East (as the Satsuma becomes more known) that the Satsuma is far superior in quality to the Tangerine. This is in our judgment sufficient reason why we should not divide our efforts by raising tangerines.

With reference to other varieties, such as the Creole Sweet, the Imperial Navel, etc., etc., we find that when grafted on *Citrus trifoliata* they do equally as well as the Washington Navel. But what we have said about the Washington Navel also applies to the varieties just named and we recommend only planting one or two trees for home use if desired.

At the beginning of the citrus industry on a commercial scale in South Alabama, nearly all the growers planted from five to twenty-five per cent. in grape fruit, particularly the Duncan variety. This variety is very hardy when grafted on *Citrus trifoliata* and the quality of the fruit produced here is excellent, but as a commercial proposition it is not to be recommended because we do not believe that this section can produce grape fruit and compete with South Florida, the Isle of Pines and other sections. Another reason is that the grape fruit has been found to be the most susceptible of all *Citrus* trees grown in Alabama to Citrus Canker and the sooner the planting of grape fruit (except for home use) is discontinued the better it will be for the orange industry.

The lemon has no place in the orchards in South Alabama. Lemon trees planted in 1912 have borne fruit twice. In 1915, 1916 and 1917 they were damaged by cold weather. They are not sufficiently hardy for our



section, even if grafted on *Citrus trifoliata* stock and we cannot recommend the planting of this fruit even as a novelty.

The Kumquat grafted on *Citrus trifoliata* stock is equally as hardy as the Satsuma. It grows well in this section; it comes into bearing early (second and third year from planting); it is profitable as well as ornamental and can be planted as a border along the fence. The variety preferred by the preserve factories in the North, as well as for decorative purposes, is the oblong, (Nagami) variety. It brings fifty per cent. higher price than the small round variety (Marumi). We do not recommend the planting of kumquats in whole orchard blocks for the reason that it is a fruit that necessarily must be used for preserves and decorative purposes and consequently the demand of the market is rather limited. When planted in a limited way it is a profitable investment.

## SPRAYING

### SOUR SCAB

This is a fungous disease that attacks the young fruit. If not combatted in time small wart-like growths are formed on the fruit, making it very unattractive and unsuited for the market. In order to prevent scab on the fruit it should be sprayed immediately after it has been formed, i. e., when the petals have fallen. A weak Bordeaux solution should be used, which is prepared as directed in spray calendar, page 25.

In spraying care should be taken to cover the young fruit with the spray as thoroughly as possible. As all the petals do not fall at the same time, it is necessary that the spraying be repeated two weeks later in order to spray the fruit the petals of which have fallen after the first spray was made. The same mixture and the same strength as above should be used.

### WHITE FLY

Spray in May as soon as the White Fly has disappeared. The object of this spraying after the adult fly has disappeared is to kill as far as possible the first brood. The materials to be used are Schnarr's Insecticide, Pinewold Insecticide and Pratt's Scalecide. Where the White Fly is abundant during the summer, another spray may be necessary in the middle of the season.



after the appearance of the second brood, which is usually in July. The grower should be guided by the conditions on his own premises and if he finds the White Fly very abundant at this time another spraying should be made with the same material as recommended before. Then another spray should be made the latter part of August, not later than about the first of September. The object of spraying at this time is to kill the White Fly larvae which is the progeny of the third and last brood. It is this brood which causes most of the damage from the White Fly. See infested foliage, Plate VII, fig. 2.

#### RUST MITE AND RED SPIDER

By the first of June spraying should be made with Lime Sulphur testing 32 degrees Baume, at the rate of one gallon of stock solution to 75 gallons of water. Care should be taken that the fruit is thoroughly covered with the solution and of course the foliage as well. We recommend that another spraying with Lime Sulphur solution be made during the month of July and another in August to prevent any russetting of the fruit.

#### SOFT SCALE

Some seasons the Soft Scale attacks the orange trees rather severely. During the summer of 1917, the growers had a very hard time to control this insect. We saw orchards where the trees, both foliage and fruit, were literally covered with the black mold which grows on the honey dew produced by the insects. The scales are usually found on the under side of the leaf and young twigs. They sap the strength out of the tree and prevent its normal development.

If the insects are not combatted in time the result is the fruit is nearly black at the time of ripening and washing the fruit becomes necessary before it can be marketed. It is evident that it is more economical to spray the tree in order to prevent the formation of black mold than it is to wash the fruit after it has been picked.

Spraying material for the control of Soft Scale is the same as used for the White Fly, excepting that three or four pounds of whale oil soap should be added to every fifty gallons of spraying solution, as we find that neither Senarr's Insecticide, Pinewold Insecticide nor Scalecide are sufficiently strong to control this insect. Trees should be examined at least every two weeks to ascertain whether or

not Soft Scale is present and if found in even small numbers, the tree should be sprayed.

#### PURPLE SCALE

Purple Scale attacks the tree as well as the fruit and if left alone will kill a young tree in one or two seasons. The insect is controled in the same manner and with the same spraying material we have recommended for Soft Scale.

In the fall after the fruit has been gathered, every orchard should be given a thorough spraying with one of the three oil emulsions mentioned with the addition of three or four pounds of whale oil soap to every fifty gallons of spraying solution.

If Rust Mite and Red Spider have been much in evidence during the growing season, another spraying with Lime Sulphur should be made during the winter-strength 1 to 35.

#### SPRAYERS

Wherever possible a power sprayer should be used in order to get the necessary pressure from 150 to 200 pounds. The small knapsack sprayer or any other small sprayer that can be carried around is unsatisfactory for the reason that not as high pressures are obtained to carry the spraying material in a fine mist. If the orchard is not large enough to warrant the owners investing in a power sprayer, several small orchard owners may combine and buy a power sprayer together. In this case care should be exercised; if any communicable disease is present in an orchard the sprayer, wagon, team and men should be disinfected before leaving such orchard with either formalin solution 1 to 120 or with bichloride of mercury solution 1 to 1 000.

# SPRAY CALENDAR CITRUS FRUITS

| Spraying     | Disease or Insect        | Time of Application                                                                                                                                                                      | Spray Materials for 50 Gal. Solution                                                                                                                                                                                                                                                          |
|--------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| First -----  | Sour scab.               | Immediately after petals have fallen. Repeat two weeks later.                                                                                                                            | Bordeaux mixture made as follows: Dissolve 3 lbs. of sulphate of Copper and 3 lbs. of unslacked lime separately in 10 gallons water for each; after being so dissolved pour the two solutions together into the spray barrel containing 30 gals. of water, making 50 gals. spraying solution. |
| Second ----- | White Fly.               | Spray in May as soon as fly has quit swarming; repeat in July after the appearance of the second brood; a third spraying should be given in August if White Fly is present in abundance. | Use Schnarrs Insecticide, Pine-wold Scale Insecticide or Scalecide. The above materials have been found to be of equal value. See direction for use on containers.                                                                                                                            |
| Third -----  | Rust mite and red spider | Spray June 1st, July 1st, Aug. 1st, and the middle of September.                                                                                                                         | Use lime-sulphur solution, 1 to 50, testing 32 degrees Baume.                                                                                                                                                                                                                                 |
| Fourth ----- | Soft scale               | Spray at the time you spray for White Fly.                                                                                                                                               | Use the same spraying solution as for White Fly with the addition of 3 to 4 lbs. of whaleoil soap.                                                                                                                                                                                            |
| Fifth -----  | Purple scale             | Spray at the time you spray for White Fly.                                                                                                                                               | Use the same spraying solution as for White Fly with the addition of 3 to 4 lbs. of whaleoil soap.                                                                                                                                                                                            |

## SUMMARY

The orchard site must be chosen with reference to favorable air drainage, air currents and freedom from wind breaks, swamps and wind stops.

The most resistant trees to freeze were those which were most perfectly cultivated and fertilized and, therefore, most vigorous.

The Satsuma is undoubtedly the most desirable of all citrus fruits for Alabama planting when considered for their commercial value and freeze resistance.

A freeze which merely causes complete defoliation may not seriously affect the season's crop immediately following.

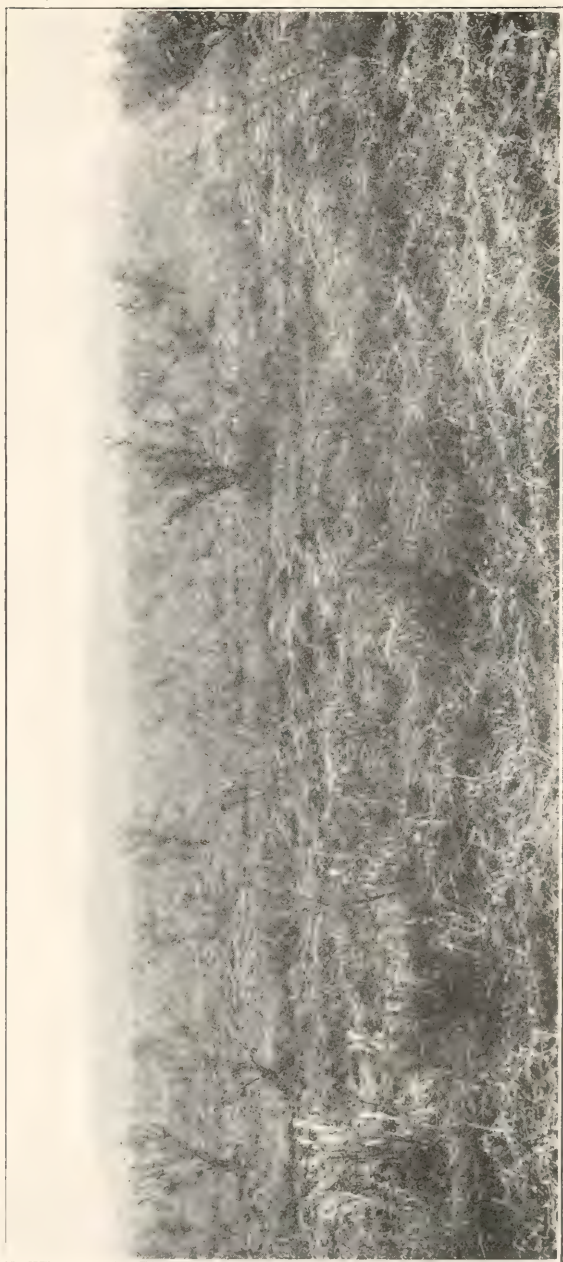
Banking in most cases proved effective. Banking should be done in early November but many orchards were saved by banking as late as January, the most damaging freeze of 1916-17 having occurred February 3rd, 1917.

The final success of the orchard depends on proper spraying.

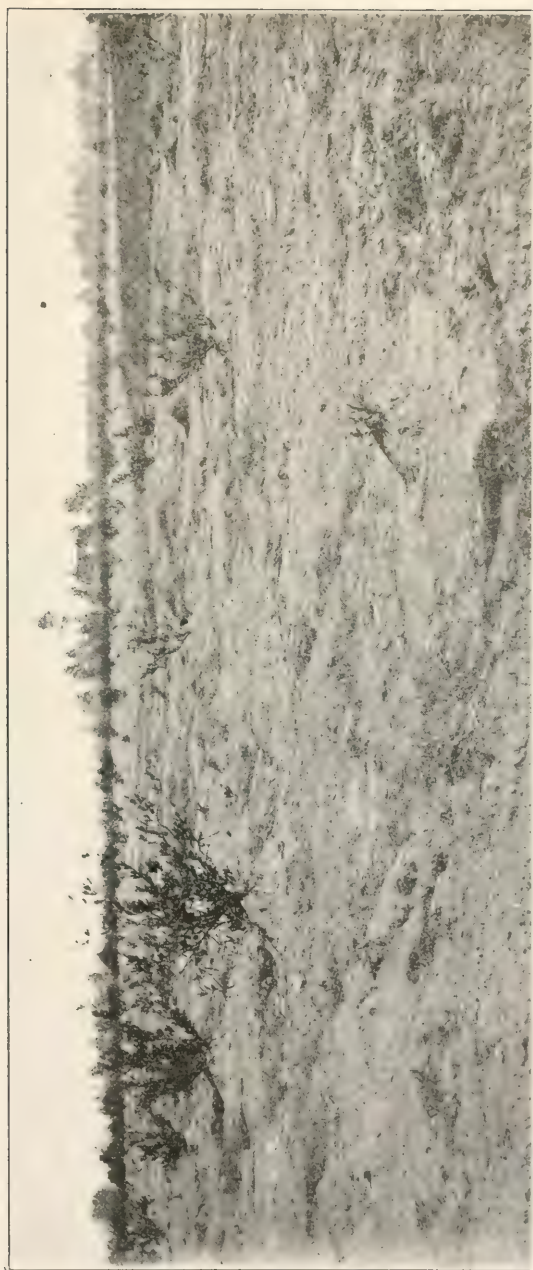


The grove in the foreground was given clean cultivation throughout the year 1916. The February freeze of 1917 did not even cause defoliation. The grove in the background beyond the road is older than the one in the foreground. It did not receive late clean cultivation during the year 1916. The grove was completely defoliated and some trees killed by the February freeze of 1917. Late clean cultivation is a protection against freezes.





Note the dead wood, lack of cultivation and general devitalized condition of the trees. Freezes, insects and diseases cause heavy losses in neglected groves like this.



In practically level areas in February, 1917, killing was much heavier near swamps. Note heavy cover of grass just turned under, and falling foliage. The falling foliage is due to lack of cultivation during 1917, and the December freeze of 1917.

PLATE IV.



Fig. 1. Heavy losses from February freeze, 1917, caused by wind break on the northwest and swamp on the north. Where corn shocks are seen Satsuma trees were killed. Only two Satsuma and a few persimmon trees appear in the picture.



Fig. 2. Low heading encourages symmetry and natural grafts, which give great bracing strength to the tree during storms and heavy fruiting periods. Note the five points of contact of the natural grafts.





Fig. 1. This tree was properly planted and given a desirable low head as was Fig. 2. In addition it has had careful pruning. Note the uniform thickness of the tree throughout; also, its tendency to stand erect and carry a general symmetrical shape. This tree can safely carry a much heavier crop of fruit than can Fig. 2. Careful pruning is the only difference between the two trees.



Fig. 2. This tree was properly planted and given a desirable low head, but it has not been carefully pruned. Note the branches on the back side of the tree are high, thin, and irregular and will not carry a heavy crop of fruit. Note also the branches in the foreground resting on the ground. Fruit on these branches is easily soiled during rainy or windy weather and if tree is near the house fowls may destroy the fruit.



Fig. 1. High headed Satsuma trees are undesirable. They are not strong or symmetrical and cannot safely carry heavy crops. They are not likely to develop cross grafts.



Fig. 2. This photograph shows an orange grove that was cultivated one way with a tractor in December and is being cultivated the other way in January. The first row of trees to the right of the tractor shows the thoroughness of the work. This is an efficient and economical method of cultivation for the orange groves. The tractor may be used to follow the late fall and winter plowing where a heavy growth of velvet beans has been turned under, or where peanuts (as in the picture) or a moderate growth of cowpeas are to be turned under. It may precede or take the place of the plow.





Fig. 1. Note perfect foliage due to clean cultivation throughout the year of 1917. This field is adjacent to field shown in Plate III. The pictures were made on the same date, January 8, 1918. Note also method of banking.



Fig. 2. Characteristic appearance of foliage infested with White Fly.



**BULLETIN No. 200**

**MARCH, 1918**

**ALABAMA**  
**Agricultural Experiment Station**

OF THE

**Alabama Polytechnic Institute**

**AUBURN**

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**Tests of Varieties of Corn at Auburn**

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By

**E. F. CAUTHEN**

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1918

**Post Publishing Company**  
**Opelika, Ala.**

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## SUMMARY.

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Since 1906, fifty-four varieties of corn have been tested on the Station Farm. During this period among the four most productive varieties of each year, Hastings Prolific and Mosby each were included six times; Sanders and Alexander Prolific each five times; Unimproved Henry Grady three times; Weekly, Garric, and Improved Henry Grady each two times; and Stone, Shaw, Davis Poor Land, Jackson Red Cob, Coker E-1 and McGregor each one time.

The prolific and medium prolific varieties afforded larger average yields than did the non-prolific or those having a tendency to produce only one large ear to the plant.

Most of the small and medium ear varieties, including Mosby, Sanders, Hastings, Davis Poor Land, Alexander Prolific, Whatley, Vardaman, and Hickory King, have more than 85 percent of grain by weight on the husked ear. The varieties having less than 80 percent are Local White, Improved Henry Grady, Shaw, and Riley Favorite—all large ear varieties.

Classified according to time required to mature, the very early and very late varieties ranked lowest in yield; the intermediate, highest.



## TESTS OF VARIETIES OF CORN AT AUBURN.

## INTRODUCTION

In 1906, Director J. F. Duggar began a series of corn variety tests to determine which are well adapted to Alabama. His plan has been closely followed for twenty-two years. The results up to 1905 were published in bulletins 76, 88, 111, and 134, now out of print. This bulletin contains the results of the tests from 1906 to 1917 inclusive.

All tests at Auburn were made on sandy or gravelly upland loam. The corn crop was usually preceded by some winter cover crop like crimson clover or rye, which was plowed under for soil improvement in the early spring. Usually a home mixed fertilizer consisting of 200 pounds of acid phosphate, 160 pounds of cottonseed meal, and 100 pounds of kainit per acre was applied in the drill at planting time or as a side application to the young corn. When the plants were from two to four feet high, from 50 to 100 pounds of nitrate of soda per acre was applied as a side dressing.

The corn was planted in checks 4 2-3 feet by 3 feet. Cultivation was usually continued until the corn began to bunch for tasseling. Whenever the stand of plants was badly defective on any plot, the yield was calculated to a perfect stand of plants. No fodder was pulled from the plants of any test. To correct for inequalities of soil, the rows of each variety were repeated at regular intervals in the field.

## ACTUAL YIELDS OF VARIETIES OF CORN AND THEIR RANK

Tabel I gives the yields of grain of the different varieties which were planted for three years or more and their rank. It shows that no one variety leads each year, but that some varieties lead or stand near the top every year. Such varieties may be relied upon as the best for similar conditions.

The average yield and rank of the different varieties in this table were not tabulated, because all the varieties did not occur every year. Obviously it would be unfair to compare the average yield of a variety grown only in favorable years with one grown in unfavorable years.

TABLE I.—Yields Per Acre and Ranks of Varieties of Corn from 1906 to 1917.

| VARIETY                   | 1906  |       | 1907  |       | 1908  |       | 1909  |       | 1910  |       | 1911  |       | 1912  |       | 1913  |       | 1915  |       | 1916  |       | 1917  |       |
|---------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                           | Bush. | Rank. | Bush. | Rank. | Bush. | Rank. | Bush. | Rank. | Bush. | Rank. | Bush. | Rank. | Bush. | Rank. | Bush. | Rank. | Bush. | Rank. | Bush. | Rank. | Bush. | Rank. |
| Alexander Prolific        | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 34.9  | 1     | 35.3  | 2     | 41.4  | 3     | ---   | ---   | 42.5  | 3     | 37.3  | 2     |
| Batts                     | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 29.3  | 10    | ---   | ---   | ---   | ---   | ---   | ---   | 37.5  | 10    | ---   | ---   |
| Bradbury                  | ---   | ---   | ---   | ---   | 30.4  | 5     | 32.0  | 6     | 34.9  | 14    | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   |
| Cocke Prolific            | ---   | ---   | ---   | ---   | 25.7  | 10    | 28.9  | 11    | 40.5  | 4     | 25.1  | 14    | 30.4  | 11    | ---   | ---   | 30.9  | 18    | ---   | ---   | ---   | ---   |
| Coker E-1                 | 24.3  | 9     | 30.8  | 5     | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 28.6  | 13    | 43.3  | 2     | ---   | ---   | 38.2  | 7     | ---   | ---   |
| Davis Poor Land           | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 38.5  | 8     | 29.5  | 9     | 31.4  | 5     | 54.3  | 4     | ---   | ---   | ---   | ---   |
| Garlic                    | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 47.0  | 1     | 33.8  | 4     |
| Godbey                    | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 33.8  | 14    | 28.1  | 11    |
| Greenwood                 | ---   | ---   | ---   | ---   | 24.0  | 13    | ---   | ---   | ---   | ---   | 26.9  | 12    | ---   | ---   | 32.9  | 15    | 48.1  | 12    | ---   | ---   | ---   | ---   |
| Hastings Prolific         | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 50.6  | 3     | 31.5  | 4     | 43.3  | 2     | 55.3  | 2     | 38.2  | 7     | 38.0  | 1     |
| Humbree                   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 40.2  | 5     | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   |
| Hickory King              | 22.0  | 15    | 20.3  | 8     | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 31.5  | 17    | 40.8  | 17    | ---   | ---   | ---   | ---   |
| Improved Henry Grady (a)  | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 30.5  | 4     | 35.8  | 1     | 40.2  | 5     | 52.2  | 6     | 36.8  | 11    | 26.1  | 14    |
| Improved Henry Grady (b)  | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 30.1  | 5     | 29.5  | 12    | 38.5  | 8     | 48.5  | 11    | 34.3  | 12    | 25.3  | 15    |
| Improved Sta. Yellow (c)  | ---   | ---   | ---   | ---   | ---   | ---   | 31.1  | 9     | 40.9  | 3     | 30.1  | 5     | 30.6  | 10    | 35.1  | 11    | 52.2  | 6     | 38.3  | 5     | 29.9  | 9     |
| Improved Sta. Yellow (d)  | ---   | ---   | ---   | ---   | ---   | ---   | 32.1  | 5     | 39.7  | 6     | 30.0  | 6     | 28.5  | 14    | 30.1  | 19    | 51.8  | 9     | 38.3  | 6     | 29.5  | 10    |
| Jackson Red Cob           | ---   | ---   | ---   | ---   | 25.5  | 11    | 33.0  | 4     | 33.0  | 18    | 28.9  | 11    | 31.1  | 7     | 31.9  | 16    | 45.7  | 13    | 34.2  | 13    | 26.8  | 13    |
| Local White               | 25.4  | 5     | ---   | ---   | 28.3  | 7     | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 34.0  | 12    | ---   | ---   | ---   | ---   | ---   | ---   |
| Marlboro                  | 28.3  | 2     | 34.7  | 1     | 29.8  | 6     | 28.3  | 12    | 35.0  | 13    | 29.6  | 8     | 31.0  | 8     | 38.7  | 7     | 55.0  | 3     | 41.9  | 4     | 28.0  | 12    |
| McGregor                  | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   |
| Mosby                     | ---   | ---   | ---   | ---   | 30.8  | 3     | 31.6  | 7     | ---   | ---   | 31.2  | 2     | 32.2  | 3     | 38.9  | 6     | 52.6  | 5     | 36.8  | 11    | 30.2  | 8     |
| Pee Dee                   | ---   | ---   | 31.4  | 3     | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   |
| Sanders                   | 26.0  | 3     | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   |
| Shaw                      | 28.9  | 1     | 30.9  | 4     | 31.7  | 2     | 36.2  | 1     | 37.7  | 9     | 30.6  | 3     | 30.6  | 10    | 35.3  | 10    | ---   | ---   | 37.9  | 8     | ---   | ---   |
| Unimproved Henry Grady    | 25.7  | 4     | 28.0  | 6     | 30.4  | 5     | 33.9  | 2     | 45.1  | 1     | 30.1  | 5     | 30.8  | 9     | 33.5  | 13    | ---   | ---   | 37.7  | 9     | ---   | ---   |
| Unimproved Station Yellow | 24.7  | 7     | 33.0  | 2     | 30.6  | 4     | 31.6  | 8     | ---   | ---   | ---   | ---   | ---   | ---   | 33.2  | 14    | ---   | ---   | ---   | ---   | ---   | ---   |
| Watson                    | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   |
| Weekley                   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   |
| Whatley                   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | ---   | 40.5  | 4     | 52.0  | 7     | 44.3  | 2     | 36.0  | 3     |

The question is often asked, "What is the best variety to plant?" The table of yields shows that the leading variety one year may not be the next year, because the weather conditions favorable to it may not prevail. However, those varieties like Mosby, Marlboro, Hastings, Alexander Prolific, Sanders, etc., that have led or been among the leaders many times can be recommended.

Among the most productive varieties of each of the eleven years covered by the above table, Hastings and Mosby each were included six times; Sanders and Alexander Prolific each five times; Unimproved Henry Grady three times; Weekley, Garric, and Improved Henry Grady each two times (tested against a larger number of varieties than Unimproved Henry Grady was); and Stone, Shaw, Davis Poor Land, Jackson Red Cob, Coker E-1, and McGregor each one time.

*Marlboro* variety occurred each year in the test with from fourteen to twenty varieties, and made an average of 108; that is, averaged 8 percent above the average of all varieties.

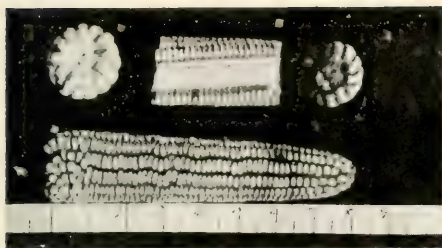
It is a prolific variety; the stalk is medium in size; the cob is white; and the kernels are hard and fairly deep.

*Mosby* occurred ten times and made an average of 109 and a ranking of 4.1. It is one of the most productive prolific varieties. Its ears are medium size; its kernels medium hard; it has a white cob.

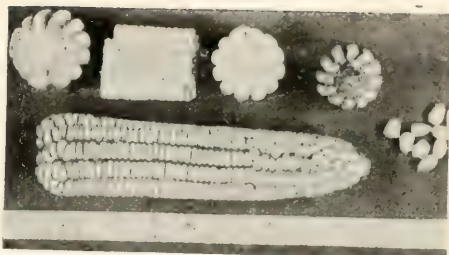
*Sanders* appears nine times in the table and makes an average of 111. The ears of this variety are short, though larger in diameter than Mosby or Marlboro. The kernels are deep, rather soft and subject to injury by weevils. Its cob is white.

*Jackson Red Cob* is a typical non-prolific variety. It requires 124 ears and nubbins to shell a bushel. The average yield for nine years is 94, or 6 percent below the average of all varieties for those years tested. Its kernels are deep and medium hard. It has a red cob.

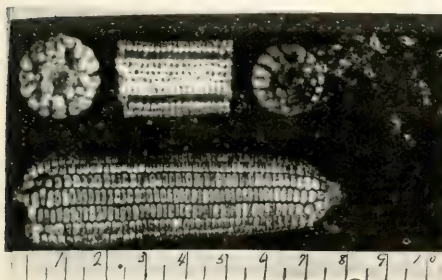




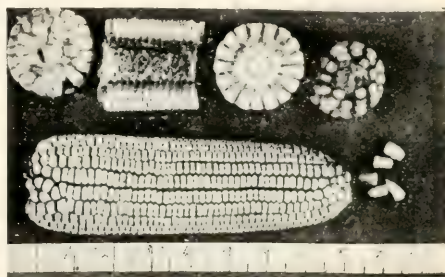
Alexander Prolific



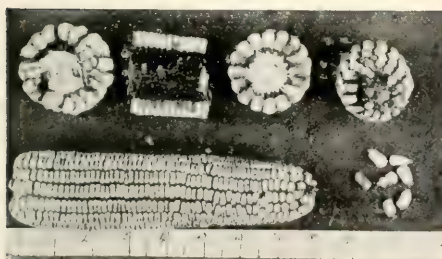
Garric



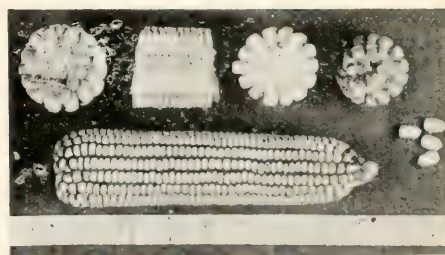
Hastings Prolific



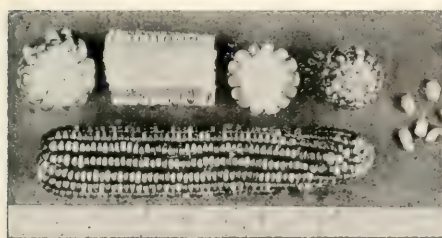
Improved Henry Grady



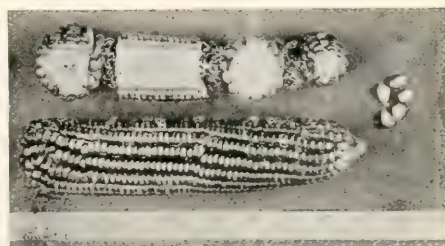
Improved Henry Grady No. 1005



Batts

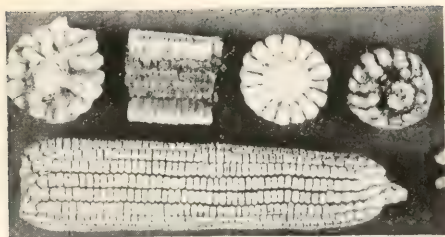


Improved Station Yellow No. 905

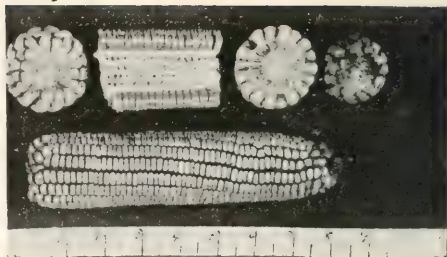


Improved Station Yellow No. 906

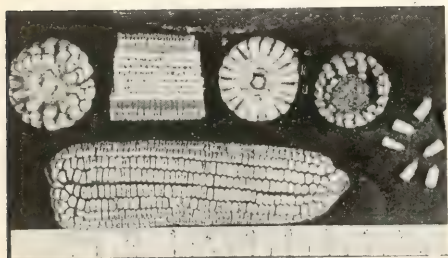
PLATE II.



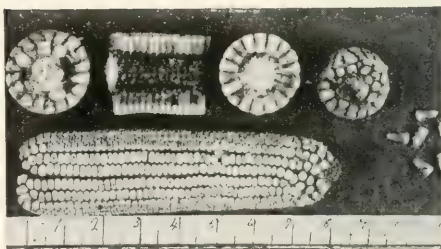
Henry Grady



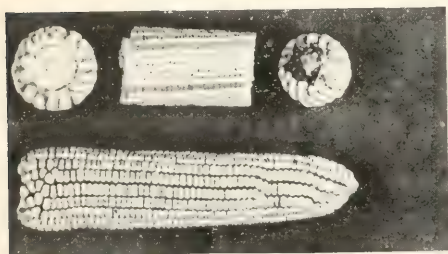
Marlboro



Watson



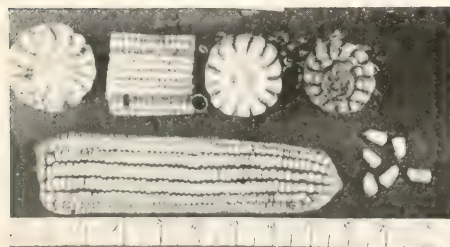
Jackson Red Cob



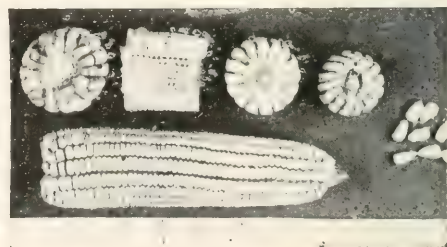
Mosby



Whatley



Weekley



Sanders



## RELATIVE YIELD OF VARIETIES OF CORN AT AUBURN

In the following table the average yield of all varieties for each year is taken as a standard for that year, or as 100 percent. The yields of each variety are then expressed in terms of percentage. The following table shows the average percentage yield of each variety for all the years during which it was tested:

TABLE II.—*Average Percentages of Yields of Varieties of Corn at Auburn, Taking the Average Yield of all Varieties of each Year as 100; Number of Ears and Nubbins Required to Shell a Bushel of Grain.*

| Varieties                  | Years Tested | Average | Number of ears and nubbins per bushel |
|----------------------------|--------------|---------|---------------------------------------|
| Marlboro -----             | 11           | 108     | 152                                   |
| Mosby -----                | 10           | 109     | 146                                   |
| Sanders -----              | 9            | 111     | 145                                   |
| Jackson Red Cob -----      | 9            | 94      | 124                                   |
| Imp. Sta. Yellow* -----    | 8            | 101     | 171                                   |
| Imp. Sta. Yellow* -----    | 8            | 98      | 153                                   |
| Hastings Prolific -----    | 7            | 109     | 156                                   |
| Imp. Henry Grady** -----   | 6            | 102     | 107                                   |
| Imp. Henry Grady** -----   | 6            | 96      | 128                                   |
| Shaw -----                 | 5            | 102     | 98                                    |
| Unimp. Henry Grady** ----- | 5            | 111     | 100                                   |
| Davis Poor Land -----      | 5            | 102     | 135                                   |
| Alexander Prolific -----   | 5            | 115     | 167                                   |
| Unimp. Sta. Yellow* -----  | 4            | 120     | 127                                   |
| Local White -----          | 4            | 98      | 122                                   |
| Whatley -----              | 4            | 113     | 163                                   |
| Greenwood -----            | 4            | 92      | 162                                   |
| Hickory King -----         | 3            | 92      | 154                                   |
| Godbey -----               | 3            | 88      | 145                                   |
| Riley Favorite -----       | 3            | 59      | 165                                   |
| Coker E-1 -----            | 3            | 103     | 127                                   |
| Bradbury -----             | 3            | 100     | 120                                   |
| Weekley -----              | 3            | 110     | 163                                   |

\*In the column of averages the Unimproved Station Yellow is larger than its improved strains; they were planted in different years except in 1909 when two of the improved strains exceeded the yields of the parent unimproved variety.

\*\*The above note applies to Unimproved Henry Grady and its selected strains.

### *Size of Ears in Different Varieties*

The number of ears and nubbins required to shell a bushel of grain is shown in Table II. Every cob that had grain on it is classified either as an ear or a nubbin.

The number of ears and nubbins that a variety produces is largely a character of that variety. In the five years that Shaw was tested it never produced ears and nubbins so small that it required over 110 to shell a bushel. In the eleven years that Marlboro was tested it never grew ears and nubbins so large that it did not require 138 or more to shell a bushel.

The wide range in size is seen when a comparison is made between Shaw and Alexander Prolific, Shaw requiring only 98 ears and nubbins to shell a bushel and Alexander Prolific 167.

The column of averages suggests the number of ears and nubbins of a variety that a farmer must handle to get a bushel of grain. It should be borne in mind that the proportion of ears to nubbins of a variety in any year depends, to some extent, upon seasons, fertilizer, cultivation, etc. The average percentage of grain from *unhusked* ears and nubbins, when practically all the husk is pulled with the ear, varies from about 70 to 78 percent of the gross weight. The large ear varieties have a lower percentage of grain than most prolific varieties.

The percentage of grain on *husked* ears and nubbins averages about 82. Those varieties having over 85 per cent are Mosby, Sanders, Hastings, Davis Poor Land, Alexander Prolific, Whatley, Vardaman, and Hickory King—all prolific. Those having less than 80 per cent of grain are local White, Unimproved Henry Grady, Shaw, and Riley Favorite—all large ear varieties.

#### RELATION OF TYPE OF PLANT TO YIELD

The type of plant seems closely related to the yield of grain per acre. Classifying the varieties into groups according to the number of ears per plant, it is observed that the group having a tendency to produce two or more ears per plant leads in production, and that it is closely followed by the medium prolific group and less closely by the non-prolific group.

The number of ears per plant of any variety depends not only upon the natural inherent characteristics of the variety, but to some extent upon the fertility of the land, seasons, cultivation, and other factors.

In the following classification those varieties that make 145 or more ears and nubbins per hundred plants are classified as prolific; those that make 125 or less ears and nubbins on a hundred plants are

classed as non-prolific; and those that make from 126 to 144 ears and nubbins per hundred plants are classed as medium prolific.

Classified according to the number of ears and nubbins per plant, the varieties tested may be divided into the following groups:

#### PROLIFIC VARIETIES

|                         |                |
|-------------------------|----------------|
| Alexander Prolific      | McGregor       |
| Albermarle              | Mosby          |
| Batts                   | Marlboro       |
| Biggs Seven Ear         | Pee Dee        |
| Cocke Prolific          | Riley Favorite |
| Greenwood               | Sanders        |
| Hickory King            | Whatley        |
| Hastings Prolific       | Weekley        |
| Improved Station Yellow | Vardaman       |
| Lowman Yellow           |                |

#### MEDIUM PROLIFIC

|                        |                           |
|------------------------|---------------------------|
| Boone Co. White (Ind.) | Improved Henry Grady      |
| Coker E-1              | Reid Yellow Dent          |
| Davis Poor Land        | Unimproved Station Yellow |
| Garric                 | Schwill                   |
| Godbey                 | Littlejohn                |

#### NON-PROLIFIC

|                         |                     |
|-------------------------|---------------------|
| Bradbury                | Tennessee Red Cob   |
| Boone Co. Special       | Tatum               |
| Improved Henry Grady    | White Giant         |
| Improved Station Yellow | McMackin Gourd Seed |
| Jackson Red Cob         | No. 77 U. S. D. A.  |
| Local White             | Iowa Silver Mine    |
| Renfro                  | Humbree             |
| Shaw                    | Hildreth            |
| Strawberry              |                     |

#### AVERAGE YIELDS OF TYPES OF CORN IN BUSHELS PER ACRE

| Year                 | Prolific | Medium Prolific | Non-Prolific |
|----------------------|----------|-----------------|--------------|
| 1906                 | 24.7     | 22.5            | 24.4         |
| 1907                 | 23.8     | 21.5            | 18.5         |
| 1908                 | 26.6     | 30.6            | 28.6         |
| 1909                 | 37.6     | 31.6            | 32.0         |
| 1910                 | 39.0     | 38.5            | 37.7         |
| 1911                 | 33.6     | 29.8            | 29.8         |
| 1912                 | 31.1     | 29.8            | 31.5         |
| 1913                 | 38.0     | 39.5            | 33.9         |
| 1915                 | 50.3     | 51.4            | 46.8         |
| 1916                 | 38.3     | 39.8            | 33.9         |
| 1917                 | 31.5     | 29.5            | 31.7         |
| 11 years of averages | 34.0     | 33.1            | 31.6         |

## THE VARIETIES CLASSIFIED ACCORDING TO SIZE OF EARS

The varieties may be classified according to size of ears into Large Ear, Medium Ear and Small Ear Varieties.

## LARGE EAR VARIETIES

|                         |                   |
|-------------------------|-------------------|
| Bailey                  | Pee Dee           |
| Boone Co. Special       | Renfro            |
| Boone Co. White (Ind.)  | Stone             |
| Boone Co. White (Tenn.) | Strawberry        |
| Bradbury                | Schwill           |
| Crawford                | Shaw              |
| Fry                     | Tennessee Red Cob |
| Hild eth                | Tatum             |
| Improved Henry Grady    | 77 U. S. D. A.    |
| Jackson Red Cob         | White Giant       |
| Local White             | Watson            |
| McMackin Gourd Seed     |                   |

## MEDIUM EAR VARIETIES

|                            |                  |
|----------------------------|------------------|
| Coker E-1                  | Mosby            |
| Davis Poor Land            | Marlboro         |
| Garrie                     | McGregor         |
| Hybrid (H. G. X Hastings)  | Reid Yellow Dent |
| Improved Expt. Sta. Yellow | Sanders          |
| Littlejohn                 | Weekley          |
| Lowman Lellow              |                  |

## SMALL EAR VARIETIES

|                    |                   |
|--------------------|-------------------|
| Alexander Prolific | Hastings Prolific |
| Albermarle         | Hickory King      |
| Batts              | Iowa Silver Mine  |
| Biggs Seven Ear    | Leaming           |
| Benton             | Riley Favorite    |
| Cocke Prolific     | Whatley           |
| Greenwood          | Vardaman          |
| Godbey             |                   |

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**ALABAMA**

**Agricultural Experiment Station**

**OF THE**

**Alabama Polytechnic Institute**

**AUBURN**

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**The Development of Soluble Manganese in  
Acid Soils as Influenced by Certain  
Nitrogenous Fertilizers**

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**By**

**M. J. FUNCHESS**

**Associate Agronomist**

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# THE DEVELOPMENT OF SOLUBLE MANGANESE IN ACID SOILS AS INFLUENCED BY CERTAIN NITROGENOUS FERTILIZERS.\*

By

M. J. FUNCHESS

Associate Agronomist, Alabama Polytechnic Institute

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## INTRODUCTION

In the spring of 1913 a series of plots on the Alabama Experiment Station Farm was devoted to a field study of the rate of nitrification of dried blood, cotton seed meal, and calcium cyanamid. The amount of fertilizer applied to the several plots was sufficient to supply seventy-seven pounds of nitrogen per acre. An attempt was made to prevent leaching on small areas of some of these plots by protecting them against rainfall with covers during the winter of 1915-1916. During the period, it was noticed that a brown crust had accumulated under some of the covers on the fertilized plots. Nitrate determinations made on this brown soil crust showed a nitrate content as high as 4959 p. p. m. of nitrates with an average of 2269 p. p. m. as the result of six determinations.

Soil taken from beneath these covers and used in a pot experiment with corn in the green house, proved to be less productive than unfertilized soil which contained only a normal amount of nitrates. In a similar experiment with sorghum as the plant indicator, the plants made little growth and finally died on the high nitrate soil. On the other hand, pots to which lime had been added made a vigorous growth and developed normally. The work suggested that this acid soil, when carrying a high nitrate content, contained some substance which was injurious to plants, and that liming reduced or prevented the injury.

An effort was made to determine the nature of the basic material in the extract of this soil, but lack of time prevented the completion of the work. Enough progress was made, however, to show that the extract

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\*The writer hereby expresses his appreciation of the faithful and efficient assistance rendered by S. A. Wingard and F. W. Parker in the prosecution of the work here reported.

from the high nitrate soil gave quite a precipitate with hydroxides.

This work was actively resumed in the fall of 1916. On October 21, the plots were prepared and fertilized as usual, a part of the fertilized plots again being covered to protect them from rainfall. The characteristic brown crust again appeared on the surface beneath the covers; and during a rather long rainless period the entire surface of some of the plots showed the brown incrustation. From this crusted surface, a bulk supply of soil was collected and taken to the laboratory for a study of the water soluble constituents therein. Continuing the work which had been started in the spring, water extracts of the high nitrate soil were analyzed, and were found to contain but little chlorides or sulphates, but enormous amounts of nitrates. Iron and aluminum were present in mere traces, or absent; but in every instance where the nitrate content of the soil was high, a large amount of manganese was found. On the contrary, in no case was a large amount of soluble manganese found in the soil from these plots, if the nitrate content was low. It was apparent, then, that there was some correlation between nitrate production and the development of soluble manganese in this acid soil. And since soluble manganese in appreciable quantities is toxic to plants, it was apparent, further, that it was the soluble manganese that was causing the injury to corn and sorghum in the pot experiments before mentioned.

It is the aim of this paper to report the work done in the effort to show whether or not soluble manganese is the cause of injury to plants grown in these soils, and if the process of nitrification is the cause of the development of soluble manganese.

#### REVIEW OF LITERATURE

A search through the literature shows that, while a large amount of work has been done with soluble manganese salts added to soils, but little study has been made of the water soluble compounds of manganese normally appearing in soils. Heretofore, the studies have been made chiefly on the assumption that there was a deficiency of such soluble compounds, and that, by their application, plant growth might be increased. Reviews of the literature bearing on this phase of the subject have been made by Kelley (8),\* Skinner (18),

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(\*) Reference is made by No. to "Literature Cited" P. 41.

and others, and will not be taken up here. Suffice it to say that the results obtained by various experimenters are quite conflicting; some obtaining beneficial results, others negative results, and still others injury. Most workers are agreed, however, that application of soluble manganese compounds in amounts much greater than 50 pounds per acre are likely to cause injury, even where smaller amounts have produced increased yields.

With regard to the presence of water soluble manganese in soils, Kelly and McGeorge (9) report the analysis of 12 Hawaiian soils representing a very wide range, including normal and abnormal types. Of the 12 soils studied, 3 had more than 20 p. p. m. of soluble  $Mn_2O_4$ , while only two had less than 5 p. p. m. Drying these soils at 100° C. increased the solubility of manganese in 9 of the 12 soils; and drying at 250° C. produced an increase in 11 of the 12 samples. The maximum solubilities in the soils dried at 100° C. were 161.1 and 180.5 p. p. m. respectively.

In an unproductive soil on which legumes failed, Newell (13) found considerable quantities of manganese compounds soluble in water. Examinations of the extracts made from this soil showed that it contained about twice as much manganese as calcium, and it was suggested that the occurrence of such compounds contributed largely to the sterility of this soil.

De Sornay (4) states that Boname found that the nitric acid formed through nitrification, combined in the absence of a base, with manganese. While DeSornay's own work showed a considerable solubility of manganese in 2 per cent nitric acid, not more than a trace of manganese was dissolved by water, using the same methods of extraction in each case.

In a discussion of the effect of manganese phosphate on plants, Truog (20) states that "water extracts of acid soils often contain considerable amounts of manganese. When these soils are limed, scarcely no manganese is found in the water extract. Since manganese may greatly affect chlorophyll formation especially of clover and alfalfa, it seems possible that in some cases one of the reasons why soil acidity is injurious to clover and alfalfa is the presence of considerable manganese in the soil solution and hence in a condition to enter the plants in considerable amounts. The variable deportment of manganese in its chemistry makes it



seem all the more probable that in certain cases the effect of soil acidity may be partly due to the manganese in solution."

## EXPERIMENTAL

### *Soil and Solution Cultures.*

All the pot culture work here reported was done in 2-gallon pots, in the green house. The pots were filled to within about one inch of the top with the soil to be used, after the soil had been thoroughly composited. No attempt was made to maintain a given water content in the pots, but tap water was added from time to time as the need was indicated. A part of the solution cultures was grown in pint jars, and a part in ordinary tumblers. The manner of setting up the tumbler cultures was essentially that of McCool (12).

### MANGANESE DETERMINATIONS.

The manganese determinations were made by the ammonium persulphate method, as described by Hillebrande (7). The standard used contained one p. p. m. of Mn. The comparisons were made in tall form Nessler cylinders.

### PREPARATION OF SOIL EXTRACTS

Bulk soil extracts were obtained by leaching approximately 20 pounds of soil until about 2 liters of percolate were obtained. However, these ratios were not exactly maintained. In some cases where a very concentrated solution was obtained, more than 2 liters were passed through the pot of soil. The leaching was usually done in a 2-gallon pot provided with a covered opening in the bottom; or in an inverted aspirator bottle, the bottom of which had been broken out. In either case, little difficulty was experienced in securing clear extracts.

### PRELIMINARY POT EXPERIMENTS ON SOIL WITH A HIGH NITRATE CONTENT

As stated in the introduction, preliminary work with the sandy soil from the Alabama Experiment Station Farm carrying a very high nitrate content gave disappointing yields of corn in pots in the green house, while sorghum made little or no growth under the same conditions. From a bulk supply of the soil with a high nitrate content, duplicate pots were prepared and treated as follows:



Series 1 received no treatment; series 2 was limed; series 3 and 4 were thoroughly leached. After leaching, series 3 received no further treatment, while series 4 received nitrate of soda sufficient to replace the nitrate nitrogen removed by the leaching. As soon as the soil from the pots had dried sufficiently to permit planting, the several series were planted to sorghum. When the plants were about 2 inches high, the number was reduced to 8 plants per pot. The sorghum was harvested when some of the plants were in head, and the green weights taken. One pot of each series is shown in Plate I, fig. 1, and the average weights of the crops are given in Table I.

TABLE I.—*The Effect of leaching, lime, etc., on the Growth of Sorghum in Acid Soil with a High Nitrate Content.*

| TREATMENT                                                           | Green weight<br>of sorghum:<br>grams |
|---------------------------------------------------------------------|--------------------------------------|
| Checks, no treatment -----                                          | 55.5                                 |
| Limed, 18 gr. per pot -----                                         | 263.5                                |
| Leached -----                                                       | 75.5                                 |
| Leached, $\text{NO}_3$ equivalent returned as $\text{NaNO}_3$ ----- | 278.0                                |

The plants in the check pots showed a very unhealthy color as soon as they came up. After being thinned nearly all the plants in the check pots died. For about 5 or 6 weeks the surviving plants retained the unhealthy color, the tips and margins of the leaves showing the injury most clearly. Later, these plants seemed to overcome the initial injury, and made a satisfactory growth. The plants in the limed pots made a rather poor growth for a short time, after which they grew rapidly. In the leached pots the plants made a normal growth, but appeared to lack nitrogen. The fourth series which had been leached and treated with sodium nitrate in sufficient quantity to return the nitrate nitrogen removed, made a very satisfactory growth throughout.

This work was in part repeated, using small jars of about 2 pounds capacity as the containers. Similar soil with a high nitrate content was used. The unleached soil proved to be so toxic that all plants died after a few days. The duplicate jars were replanted, and again all but one plant died. The soil that had been thoroughly leached produced normal plants, both root and top. Liming this soil in a large measure re-

moved the toxic body, although the root development was not so good as in the leached series. In still another series the soil was leached before planting, and the leachings slowly returned to the pots in the water applied to the growing plants. The plants in this series grew about as well as those in the limed series.

In all cases above discussed, each extract from the high nitrate soil had a very high concentration of manganese. The extracts contained not more than traces of iron, and very small amounts of aluminum. The data obtained justify the conclusion that the toxic body in this soil is easily removed by leaching; or is made non-toxic by the addition of lime. That the infertility is not due to the concentration of the soil solution is shown by the yields obtained from the pots to which nitrate of soda was returned to replace the nitrates leached out. Since manganese was the only unusual constituent found in quantity in the extracts, it was apparent that the infertility was due to this element, or to some soluble organic compound.

#### EXPERIMENTS TO DETERMINE THE CAUSE OF THE INFERTILITY OF THE SOIL WITH A HIGH NITRATE CONTENT

Since thorough leaching of the soil carrying a high nitrate content greatly reduced its toxicity, the leachings from this soil should contain the substance responsible for the low productive power of the soil. In order to test this, the following methods were used: Pint jars were fitted with paraffined corks, through which five holes had been bored with a small cork borer. After the jars had been prepared and treated as indicated in Table II, germinated oat seedlings were inserted in the holes in the corks, and held in place by a wrapping of cotton. The cultures were then so placed in the laboratory as to receive maximum light. At the end of about three weeks, the plants were taken down, carefully air dried and weighed. The data so obtained are given in Table II.

TABLE II.—*The Effect of Dilution and of Precipitation, on the Toxicity of a Soil Extract Containing a High Concentration of  $\text{NO}_3$  and Mn. Weight in Grams of Air Dry Roots and Tops.*

| Nature of Solution                                       | Untreated |      |       | Precipitated |      |       |
|----------------------------------------------------------|-----------|------|-------|--------------|------|-------|
|                                                          | Root      | Top  | Total | Root         | Top  | Total |
| Tap water -----                                          | .110      | .125 | .235  | ---          | ---  | ---   |
| Soil extract -----                                       | .020      | .158 | .178  | .024         | .111 | .135  |
| Soil extract 50 per cent<br>dist. water 50 per cent ---  | .054      | .178 | .232  | .107         | .180 | .287  |
| Soil extract 25 per cent,<br>dist. water 75 per cent --- | .091      | .158 | .249  | .134         | .198 | .332  |
| Soil extract 10 per cent,<br>dist. water 90 per cent --- | .166      | .221 | .387  | .382         | .181 | .563  |
| Second leaching -----                                    | .186      | .197 | .383  | ---          | ---  | ---   |

When this soil extract was made alkaline with NaOH, a voluminous precipitate came down, which precipitate gradually darkened on standing. The precipitate was filtered out and  $\text{HNO}_3$  added to slight acidity. Sufficient c. p.  $\text{CaCO}_3$  was added to bring the extract back to the neutral point. In the last three columns of the table are given the yields of oats from the solutions so treated. On account of the wick-like action of the cotton wrapping around the seedlings, salts accumulated around some of the seedlings to such an extent as to become very injurious. In spite of this defect in the method used, the soil extract from which the elements precipitated by NaOH had been removed, proved to be a much better medium for growth than the original extracts of similar dilution.

A chemical examination of the second leaching from this soil showed that practically all of the manganese had been removed in the first extract. This second leaching was used as a medium for growth, with the results shown in the last line of Table II.

The evidence presented thus far shows that the brown crusted soil under discussion contains a very large amount of nitrates and soluble manganese; that this soil is a poor medium for plant growth; that leaching removes, in a large measure, the toxic body; that the water extract of this soil is highly toxic to seedling plants; and that the use of an active base markedly improves both soil and extract.

To obtain further evidence as to the cause of the toxicity of the extract of this soil, another supply of extract was obtained, and the culture method described by McCool was used. If the toxic body present were **organic** in nature, in all probability the extract would

be improved by treating it with carbon black, as suggested by the work of Scheiner (16). In this work washed carbon black was used at the rate of 10 grams per liter and filtered out.

Again, the extract was distilled in an effort to determine if any volatile toxic bodies were present. The distillation was done in the following manner: 500 cc. of the extract was placed in a Jena flask connected with a glass condenser, and distilled until the distillate amounted to 485 cc. Both the residue and the distillate were then made to 1,000 cc with distilled water. Still another portion of the extract was evaporated to dryness, burned to a red heat in a porcelain dish, the mineral residue taken up with HCl, and evaporated to dryness on the water bath. A little water was added, and the salt again evaporated to dryness, after which the dish was heated at about 100° C. until no trace of free acid could be detected. This salt was then taken up with distilled water and made to volume. The extract that was precipitated was made alkaline with NaOH, the precipitate filtered out and H<sub>2</sub>SO<sub>4</sub> added until the solution was slightly acid. Then a slight excess of c. p. CaCO<sub>3</sub> was added to bring the solution back to neutral. The sorghum cultures grown in these solutions were started May 15, and taken down June 5, 1917. The data are set forth in Table III, and photographs are given in Plate I, fig. 2.

TABLE III.—*The Effect of Carbon Black, Distillation, Precipitation, and Ignition on the Toxicity of a Soil Extract Containing a High Concentration of NO<sub>3</sub> and Mn.*

| Culture Medium                                                               | Av. air dry wt. of |      |       |
|------------------------------------------------------------------------------|--------------------|------|-------|
|                                                                              | Roots              | Tops | Total |
| Distilled water -----                                                        | .032               | .039 | .071  |
| Soil extract 50 per cent, dist. water 50 per cent, precipitated -----        | .086               | .159 | .245  |
| Soil extract 25 per cent, dist. water 75 per cent, precipitated -----        | .058               | .115 | .173  |
| Volatile part of soil extract 50 per cent, dist. water 50 per cent -----     | .031               | .040 | .071  |
| Non-volatile part of soil extract 50 per cent, dist. water 50 per cent ----- | .024               | .056 | .080  |
| Soil extract 50 per cent, dist. water 50 per cent, plus carbon black -----   | .037               | .085 | .122  |
| Soil extract ashed, 50 per cent, dist. water 50 per cent -----               | .029               | .057 | .086  |
| Dist. water plus carbon black -----                                          | .038               | .034 | .067  |
| Soil extract 50 per cent, dist. water 50 per cent -----                      | .023               | .046 | .069  |
| Soil extract 25 per cent, dist. water 75 per cent -----                      | .021               | .039 | .060  |



A study of Table III along with the photograph on Plate I, fig. 2, shows that by far the best growth was obtained from the solution that had been precipitated with caustic soda, with the carbon black treated solution ranking second. The effect of carbon black was much more pronounced on top than on root development. The duplicates in this culture failed to agree, one making twice as much root as the other. The effect of separating the extract into volatile and non-volatile parts is best seen in the photograph, since the root weight fails to give a correct idea of the toxicity of the two separates. In such cases as this, it has been found that the short, stumpy roots developed are very woody, and are much heavier than is indicated by their appearance. Ashing the extract reduced the toxicity as indicated by appearance but not as indicated by the weight of roots produced. The fact that the more dilute extract gave poorer results than the more concentrated in each case where a comparison is afforded cannot be explained.

While the evidence is not conclusive, consideration of both the data and the photograph, indicates very strongly that the cause of the toxicity of this extract is inorganic rather than organic. On account of the results obtained with carbon black, the experiment was repeated with slight variations. The ashing of the solution, the separation into volatile and non-volatile parts, and the treatment with carbon black were made in the way already described. In this instance, the precipitation was done by adding to the extract a small amount of calcium oxide and shaking vigorously for about twenty minutes, after which the solution was left over night. It was then filtered and  $\text{CO}_2$  led in until the extract gave no reaction with phenolphthalein. The portion treated with calcium chloride was given enough c. p.  $\text{CaCl}_2$  to make a N/20 solution. The second leaching was obtained immediately after the first. The data obtained and the treatments given are found in Table IV.



TABLE IV.—*The Effect of Carbon Black, Distillation, Ignition, and Precipitation, on Plant Growth in a Toxic Soil Extract*

| Nature of Solution                                            | Av. wt. root and top from |       |         |       |
|---------------------------------------------------------------|---------------------------|-------|---------|-------|
|                                                               | Peas                      |       | Sorghum |       |
|                                                               | Tops                      | Roots | Tops    | Roots |
| Tap water -----                                               | .2949                     | .0921 | .0450   | .0181 |
| Soil extract -----                                            | .1594                     | .0640 | .0402   | .0075 |
| Volatile part of soil extract -----                           | .2327                     | .1129 | .0382   | .0206 |
| Non-volatile part of soil extract -----                       | .3047                     | .1244 | .0505   | .0128 |
| Soil extract and carbon black -----                           | .2250                     | .0903 | .0471   | .0096 |
| Soil extract and $\text{CaCl}_2$ -----                        | .3458                     | .1065 | .0443   | .0106 |
| Soil extract precipitated with $\text{Ca}(\text{OH})_2$ ----- | .3796                     | .1358 | .0538   | .0177 |
| Soil extract ash -----                                        | .2893                     | .1164 | .0335   | .0107 |
| Second leachings -----                                        | .3340                     | .1214 | .0415   | .0103 |

Photographs of the peas and sorghum are shown in Plate II, figs. 1 and 2. Tap water was used in the extraction of the soil, and as a check in the cultures. The concentrated extract contained manganese equivalent to 255 p. p. m.  $\text{MnSO}_4$ , and the second leaching contained the equivalent of 17 p. p. m. The cultures grew from September 3 to September 19, 1917.

In the untreated soil extract, neither the peas nor the sorghum developed scarcely any roots, the growth of lateral roots being almost completely inhibited. The short, thickened roots were much darker than the normal. The volatile part of the soil extract proved to be a splendid medium for the growth of sorghum,—very much better than the non-volatile part. Exactly opposite results were obtained with peas, the volatile part producing less root and top than the non-volatile part. The tops of the peas grown on the non-volatile part, however, were almost white at the time the photograph was taken, and some of the leaves had dead margins. The tops of the sorghum plants were similarly affected under the same conditions. Highly bleached plants were also produced by the extract ash. Carbon black slightly improved the extract as shown by root and top development of both the plants grown, though the tops were yellow in both cases. Calcium chloride added in sufficient amount to make a N/20 solution, increased root and top development for both plants, though the peas were benefitted more than the sorghum as can be readily seen from the plant weights and the photographs. In presence of calcium chloride both plants produced tops of a normal green color.

The extract ash produced nearly twice as much growth of peas as did the untreated extract; but for sorghum, little improvement was affected by ashing.

The results of this experiment appear to show that the toxic body in this extract is organic, at least in part. But special attention is called to the use of tap water in this case. The unexpected results obtained from the non-volatile part of the extract, and the extract ashed, both of which were made to volume with tap water, warranted a careful examination of the tap water used; and it was found to carry a very considerable quantity of calcium bicarbonate in solution. Since the untreated extract was highly toxic, the toxic body should have been found in either the volatile or the non-volatile part; but in this case, both separates supported a very fair growth, quite in disagreement with the results reported in Table III, where sorghum was also used as the plant indicator. It was suggested that the results obtained might be due to the bicarbonate of calcium carried in the tap water, which served to a certain extent as an antidote to the manganese in the soil extract.

In the effort to determine whether or not the salts in the tap water were responsible for the good root and top growth in the non-volatile part, and in the ashed part of the soil extract, another test was made, using a soil extract containing manganese equivalent to 204 p. p. m. of manganese sulphate. Unfortunately, a severe storm smashed a laboratory window and blew some of the plants from the containers, making it impossible to get the complete record. Notes on root and top development had been made previous to the accident, however, and these are here given.

Boiling the extract or heating it to 80°C., had little or no effect on the toxicity. The volatile part supported a good growth of roots, and a fair growth of tops. And, in agreement with the results given in Table IV., the non-volatile part made to volume with tap water produced a good growth of both roots and tops. On the other hand, the non-volatile part made to volume with distilled water produced a fair amount of tops, but root development was almost completely inhibited.

This experiment was again repeated, with modifications, using a soil extract containing 60 p. p. m. of Mn. The results are shown in Table V.

TABLE V.—*The Effect of Distilled Water vs. Tap Water, on the Toxicity of a Soil Extract Containing 60 p. p. m. Mn.*

| Culture Medium                                                                | Peas           |       | Sorghum        |       |
|-------------------------------------------------------------------------------|----------------|-------|----------------|-------|
|                                                                               | Wt. of air dry |       | Wt. of air dry |       |
|                                                                               | Roots          | Tops  | Roots          | Tops  |
| Tap water -----                                                               | .1209          | .3005 | .0251          | .0344 |
| Distilled water -----                                                         | .1318          | .2118 | .0105          | .0269 |
| Soil extract, untreated -----                                                 | .0550          | .3819 | .0050          | .0286 |
| Volatile part of soil extract -----                                           | .1267          | .1986 | .0230          | .0304 |
| Non-volatile part of extract made to<br>volume with distilled water -----     | .0758          | .3497 | .0051          | .0208 |
| Non-volatile part of extract made to<br>volume with tap water -----           | .1626          | .3402 | .0210          | .0310 |
| Extract evaporated, ignited, dissolved,<br>made to volume with dist. water -- | .0525          | .3125 | .0063          | .0255 |
| Extract evaporated, ignited, dissolved,<br>made to volume with tap water ---- | .1686          | .3566 | .0238          | .0340 |
| Extract plus 2 gm. $\text{CaCO}_3$ per liter ----                             | .1556          | .2971 | .0306          | .0399 |

The data given in Table V fully confirm the suggestion that the salts in the tap water used\* in the previous experiments were responsible for the reduced toxicity of the soil extract which had been concentrated and again made to volume with tap water. The photographs shown on Plate III, figs. 1 and 2, show conclusively that concentrating the soil extract and making it back to volume with distilled water, had no effect on the toxicity of the solution; but when tap water was used, both roots and tops grew very well indeed. Similar results were obtained by evaporating the extract to dryness, igniting, and dissolving the residue in acid, as previously explained. When made to volume with distilled water, the toxicity was not reduced; but when made to volume with tap water, both roots and tops grew well. It should be stated, however, that in each of the tap water dilutions, the plants produced yellow tops. The untreated extract and the cultures made to volume with distilled water produced tops with a normal green color, but root growth was almost completely inhibited. Neither the sorghum nor the peas made lateral roots more than a few millimeters long. In the photograph, none of the sorghum roots in these cultures can be seen, but the stubby pea roots may be seen in tumblers No. 3 and 5. The soil extract to

\*Five hundred cc of the tap water used in this experiment required 3.3 cc. of  $\text{N}/5$   $\text{HCl}$  to titrate, using methyl orange as the indicator.

which a little calcium carbonate was added produced nearly as good peas and sorghum as did the extract which had been reduced and made to volume with tap water, or ashed, and made to volume in a similar manner. The distillate of the soil extract was slightly better as a medium for growth than distilled water made in the same glass still used in distilling the soil extract.

Evidence that the amount of manganese found in the several soil extracts used was sufficient to cause great injury to plants is here given. To the distillate of a toxic soil extract with a high manganese content, manganese sulphate was added to equal the manganese content of the original extract. Both roots and tops of plants died in this culture. In two other instances, soil extracts containing but traces of manganese, and capable of supporting a very satisfactory growth of sorghum, have been made extremely toxic through the addition of manganese sulphate at the rate of 200 p. p. m. These results are not surprising in view of the fact that McCool (12) has shown that a solution of  $N/4000 \text{ MnCl}_2$  (18 p. p. m.) is injurious, and  $N/2000 \text{ MnCl}_2$  (36 p. p. m.) prevents root growth of pea seedlings, using distilled water as the solvent.

One of the most interesting experiments tending to show the inorganic nature of the toxic body in our soil extracts is given in Table VI. The soil extract used contained 15.8 p. p. m. of aluminum, and 80 p. p. m. of manganese. The cultures grew from Dec. 8th to Dec. 29th, 1917.

The culture solution to which 3 cc. of  $N/1 \text{ NaOH}$  were added was slightly alkaline to litmus and to phenolphthalein; but those to which less than 3 cc. were added, gave no reaction with these indicators. The cultures which received lime were treated with an excess of  $\text{CaO}$ , and vigorously shaken for about 20 minutes, after which the solution was left undisturbed for several hours. The excess calcium hydroxide was then carbonated. In all of the previous experiments, the compounds precipitated by alkaline hydroxides were filtered out; but in this case, the precipitate was left in the culture medium. Special attention is called to the fact that partial precipitation proved very much more effective in reducing the toxicity of this extract than various degrees of dilution. In fact, the



dilutions used were not high enough to materially reduce the toxicity toward root development. With 50 per cent soil extract and 50 per cent distilled water, or with 25 per cent soil extract and 75 per cent distilled water, the solutions were toxic enough to seriously reduce root growth. On the other hand, with approximately 50 per cent or 75 per cent of the manganese precipitated, good root growth was obtained. Reduced toxicity of the cultures in which a part of the manganese precipitated is probably due to the antidotal action of the potassium salts formed in the culture medium. See Table VI for the data, and Plate IV, figs. 1 and 2 for the photographs of these cultures.

TABLE VI.—*The Effect of Precipitation and of Dilution on the Toxicity of a Soil Extract Containing 15.8 p. p. m. of Al., and 80.0 p. p. m. of Mn. in Solution.*

| Culture Medium                                          | Av. air dry weight of |      |
|---------------------------------------------------------|-----------------------|------|
|                                                         | Roots                 | Tops |
| Tap water .....                                         | .137                  | .234 |
| Distilled water .....                                   | .109                  | .189 |
| Soil extract .....                                      | .088                  | .222 |
| Soil extract plus 0.6 cc. N/1 NaOH .....                | .145                  | .317 |
| Soil extract plus 1.2 cc. N/1 NaOH .....                | .157                  | .269 |
| Soil extract plus 1.8 cc. N 1 NaOH .....                | .162                  | .293 |
| Soil extract plus 2.4 cc. N/1 NaOH .....                | .144                  | .259 |
| Soil extract plus 3.0 cc. N/1 NaOH .....                | .179                  | .317 |
| Soil extract plus CaO .....                             | .170                  | .318 |
| Soil extract 75 per cent, dist. water 25 per cent ..... | .097                  | .279 |
| Soil extract 50 per cent, dist. water 50 per cent ..... | .093                  | .276 |
| Soil extract 25 per cent, dist. water 75 per cent ..... | .119                  | .317 |
| Second leaching .....                                   | .154                  | .267 |

Even though a good top growth was obtained, there was practically no root development in the untreated soil extract. The addition of 0.6 cc. N/1 NaOH reduced the toxicity slightly; but this amount was not as effective as 1.2 cc. Beyond this point, increased amounts of alkali were not proportionately effective. Tests made on these culture solutions after the plants were taken out, showed that only a part of the manganese had been precipitated. This experiment strongly indicates the protective action of the sodium and the calcium salts formed with a part of the acid radicle formerly held by manganese and aluminum. Considering both the precipitation and the dilution



cultures, it would appear that the amount of soluble manganese in soil relative to the amount of other soluble bases, is more important than the actual amount of soluble manganese. The work further indicates that precipitated manganese compounds are not toxic to pea roots, since many of the roots were buried in the precipitate in the container, at the time the experiment was discontinued; and there was no injury to these, so far as could be judged by external appearances.

The writer believes that the evidence given is sufficient to justify the conclusion that the toxicity of the soils and soil extracts studied was due chiefly to inorganic compounds and that manganese is the element responsible for the toxicity observed. And since but small amounts of sulphates and chlorides were usually found, manganese nitrate is believed to be the specific form in which the soluble manganese occurs.

#### DOES NITRIFICATION DEVELOP SOLUBLE MANGANESE?

##### STUDIES ON ALABAMA SOILS

In order to throw light on this question the following experiments were performed, using two different soils. One of the soils was taken from a plot on the Experiment Station Farm which had received annual application of sulphate of ammonia, and is very sour. It is designated "soil from plot 4" in the table. The other soil was taken from the plots described earlier in this paper and is designated "soil from nitrification plots"; this soil is but moderately sour. From each of these soils, three sets of pots were prepared, each treatment being made in duplicate on each soil. One set of pots was planted to sorghum on the day that the treatments were applied; the second set of pots was planted about seven weeks later; and the third set was left unplanted. The pots of this last set were leached after 95 days, the leaching filtered through a Pasteur-Chamberland filter, and analyzed. The treatment given, the crop yields, and the analyses of the extracts, are given in Table VII. Photographs of the pots are shown on Plate V, figs. 1 and 2.

TABLE VII.—*The Effect of Nitrogenous Fertilizers on the Development of Soluble Manganese, and on Plant Growth. Early Planted Crops Only.*  
*NO<sub>3</sub> Mn., and Green Weights of Sorghum in Grams.*

| Series | TREATMENT               | Soil from<br>plot 4                            |       | Green weight of<br>crop | Soil from nitrification plots                 |       | Green weight of<br>crop |
|--------|-------------------------|------------------------------------------------|-------|-------------------------|-----------------------------------------------|-------|-------------------------|
|        |                         | Analysis of<br>leaching from<br>uncropped pots |       |                         | Analysis of<br>leaching from<br>uncr'p'd pots |       |                         |
|        |                         | NO <sub>3</sub>                                | Mn    |                         | NO <sub>3</sub>                               | Mn    |                         |
| 1      | None -----              | 1.092                                          | .0039 | 20.5 <sup>2</sup>       | 1.432                                         | .0341 | 21.5                    |
| 2      | Lime, 18 grms. -----    | 1.867                                          | trace | 104.5                   | 1.012                                         | trace | 106.0                   |
| 3      | Am. sulphate, 4.3 grm.  | 1.239                                          | .0372 | Dead                    | 1.015                                         | .0843 | 1.0                     |
| 4      | Am. sulphate and lime   | 12.424 <sup>1</sup>                            | trace | 321.5                   | 3.661                                         | trace | 373.0                   |
| 5      | Dried blood, 7 grms.--- | 2.335                                          | .0237 | 31.5                    | 2.118                                         | .0880 | 28.5                    |
| 6      | Dried blood, and lime   | 3.350                                          | trace | 330.5                   | 4.470                                         | trace | 425.0                   |

<sup>1</sup>Apparently there was an error in this determination.

<sup>2</sup>One pot omitted from average, since it was evidently abnormal.

The soil from plot 4 is a yellow rather heavy one, inclined to run together and puddle when wet. According to the Veitch method, the lime requirement is about 4,000 pounds per acre. In this experiment ammonium sulphate was nitrified but little in the unlimed pot. However, the water soluble manganese recovered by leaching was nearly ten times as great as from the unfertilized pot. Dried blood was nitrified to some extent, and the soluble manganese recovered was about seven times as great from the untreated pot. The other soil used is of a rather coarse sandy nature and leaches very readily. By the Veitch method, the unfertilized plot has a lime requirement of about 1200 pounds per acre. In this soil ammonium sulphate was not nitrified; and seemed to retard nitrification in the unlimed pots. On the other hand, dried blood was nitrified to a moderate degree, under the same conditions. Both the ammonium sulphate and the dried blood caused a very considerable increase in the soluble manganese in the unlimed pots.

Considering the plant growth, it will be seen that in both soils the addition of ammonium sulphate proved highly detrimental to sorghum in the unlimed pots. In fact, all the plants died soon after they came up. Without lime, dried blood produced but very little better growth than did the untreated soil. From the limed pots, only traces of manganese were recovered; and the growth of sorghum in these was very satisfactory. The

increased nitrification cannot be the cause of the increased yields in the limed pots, since in the sandy soil lime apparently retarded nitrification in the unfertilized pots, but increased the plant growth five fold. The manganese leached from the unlimed fertilized pot of the sandy soil is quite sufficient to cause the poor growth obtained, as can be seen from the following considerations. The optimum water content of this soil is probably about 10 per cent. On this basis the water content of the approximately 20 pounds of soil per pot would be about 1,000 cc. Assuming that the manganese recovered in the leachings existed in the soil in readily soluble form, and calculating the manganese as sulphate, the concentration of the soil solution would be above 280 p. p. m. While the amount of manganese leached from the plot 4 soil is not as great as that obtained from the nitrification plot soil, still the amounts obtained are sufficient to cause injury to plants, according to the assumptions above. Repeated leachings from this soil continued to show manganese, even after about 7 liters had been percolated, and it is doubtful if all the soluble manganese could be removed by a much more thorough leaching than this.

Most of the pots used in the above work were planted to cow peas on June 17, and harvested August 25, 1917. In the early stages of growth, the plants in the pots to which ammonium sulphate or dried blood had been added, were yellow, and had a very unhealthy appearance. Later, all plants took on a healthy green color, and made a good growth, all pots yielding about alike. At harvest time, it was found that the root system of the plants in the unlimed fertilized pots was very poorly developed, and had a scant development of tubercles. Aside from this, there was little or no apparent injury to peas, as judged by final weights of tops produced. This result with cow peas is in strong contrast with sorghum in these same pots, and with cow peas in the field. In all probability, however, these plants with poor root growth would have made a poor showing under field conditions in time of drought.

After the cow pea harvest, the pots used in this work were left undisturbed in the green house until September 24, 1917, at which time, 5 grams of ammonium sulphate and 6 grams of dried blood were applied, respectively, to those pots which had received these substances in the previous treatment. No further addition of lime was made. On October 16, one set of pots was

planted to oats, and the other, to crimson clover. A good stand of oats was obtained, but the clover came up very slowly in the unlimed, fertilized pots. On Nov. 17, all clover plants in the unlimed pots to which ammonium sulphate had been added were dead; and the unlimed dried blood treated pots carried very poor plants, some of which were dying. Of the limed pots, only those fertilized with ammonium sulphate produced unhealthy plants. All remaining clover plants were removed and English peas planted on November 17. Both the oats and the peas were harvested and weighed green on January 7, 1918. At this time, all of the peas on the unlimed pots fertilized with sulphate of ammonia were dead. Some plants in the limed pots of the sulphate of ammonia series, and the unlimed dried blood series, had such poor root development that the entire root growth was pulled out in cutting the plants with a knife. The lateral roots were mere stubs, not more than a fourth of an inch long in some instances. Oats failed on the unlimed sulphate of ammonia series, and were very poor on the unlimed dried blood series. In the limed series, with nitrogenous fertilizer, a very good growth was made. The average green weight of peas and of oats is given in Table VIII.

TABLE VIII.—*The Effect of Nitrogenous Fertilizers on the Growth of Oats and Peas, in Soil from "Plot 4" Alabama Experiment Station Farm.*

| TREATMENT                             | Av. green wt. in grams |      |
|---------------------------------------|------------------------|------|
|                                       | Oats                   | Peas |
| None -----                            | 8.9                    | 9.9  |
| Lime -----                            | 17.8                   | 13.4 |
| Am. sulphate, 5 grms. -----           | 2.1                    | Dead |
| Am. sulphate, 5 grms., and lime ----- | 62.8                   | 10.9 |
| Dried blood, 6 grms. -----            | 7.2                    | 6.3  |
| Dried blood, 6 grms., and lime -----  | 65.6                   | 14.6 |

Oat plants pulled from the unlimed fertilized pots showed severe root injury similar in appearance to that obtained with plants taken from the field, where the addition of dried blood was causing crop failure.

A further study of the influence of nitrogenous fertilizers on the development of soluble manganese was made, using the following methods. One hundred gram portions of acid soils collected from various places in Alabama, were weighed into tumblers; and to each sample was added .1 gram of ammonium sulphate in solution. Distilled water was then added to the esti-



mated optimum, and the tumblers set away in a dark closet. From time to time, distilled water was added to restore that lost by evaporation. Solutions were obtained for analysis by washing the 100 grams of soil into a jar with 500 cc of distilled water, the jar thoroughly shaken at short intervals and then allowed to settle, after which the supernatant extract was filtered through a Pasteur-Chamberland filter. The soils were incubated from June 15 to August 1, 1917. The data so obtained are given in Table IX.

TABLE IX.—*The Influence of Ammonium Sulphate on the Development of Soluble Manganese in Acid Soils. NO<sub>3</sub> and Mn. in p. p. m. of Air Dry Soils.*

| Soil No. | NO <sub>3</sub> in soil at |        | Mn in soil at |      |
|----------|----------------------------|--------|---------------|------|
|          | Start                      | End    | Start         | End  |
| 15       | trace                      | 200.0  | trace         | 5.0  |
| 39       | trace                      | 25.0   | trace         | 7.5  |
| 41       | trace                      | 130.0  | trace         | 11.0 |
| 42       | trace                      | 130.0  | trace         | 11.0 |
| 44       | trace                      | 100.0  | trace         | 7.5  |
| 45       | trace                      | 43.0   | None          | 6.5  |
| 46       | trace                      | 55.0   | trace         | 4.5  |
| 47       | trace                      | 150.0  | None          | 17.5 |
| 48       | trace                      | 55.0   | None          | 6.0  |
| 49       | trace                      | 24.0   | None          | 4.5  |
| 50       | 4.4                        | 300.0  | 3.0           | 10.0 |
| 51       | 7.3                        | 90.0   | None          | 8.0  |
| 52       | 5.3                        | 90.0   | trace         | 7.5  |
| 53       | 4.0                        | 55.0   | trace         | 10.0 |
| 54       | trace                      | 9.0    | trace         | 3.0  |
| 55       | trace                      | 150.0  | trace         | 13.5 |
| 56       | trace                      | 24.0   | trace         | 6.5  |
| 57       | 12.4                       | 210.0  | None          | 13.0 |
| 58       | 3.7                        | 200.0  | trace         | 7.5  |
| 59       | trace                      | 240.0  | trace         | 40.0 |
| 60       | trace                      | 5.5    | trace         | 3.0  |
| 61       | 13.6                       | 1100.0 | trace         | 92.5 |
| 62       | 3.0                        | 100.0  | trace         | 13.5 |
| 63       | 3.9                        | 90.0   | None          | 8.0  |
| 64       | trace                      | 13.0   | trace         | 5.0  |
| 65       | 7.2                        | 60.0   | trace         | 19.5 |
| 66       | trace                      | 650.0  | trace         | 13.5 |
| 67       | trace                      | 85.0   | None          | 12.5 |
| 68       | 6.0                        | 875.0  | None          | 8.0  |
| 69       | trace                      | 50.0   | trace         | 12.5 |
| 70       | 5.6                        | 55.0   | 2.0           | 20.0 |
| 71       | 2.5                        | 5.0    | trace         | 7.0  |
| 72       | trace                      | 30.0   | None          | 9.0  |
| 73       | 4.7                        | 150.0  | trace         | 12.5 |
| 74       | trace                      | 2.5    | None          | 4.5  |
| 75       | 3.0                        | 4.0    | 20.5          | 10.0 |
| 76       | trace                      | 38.5   | trace         | 6.5  |
| 77       | 2.5                        | 4.0    | 2.5           | 15.0 |
| 78       | trace                      | 100.0  | 6.0           | 14.0 |



As shown in Table IX, the addition of ammonium sulphate to these acid soils caused an increase in the soluble manganese in each of the soils, with the exception of number 75. In several of the soils, ammonium sulphate was nitrified so poorly that it seemed worth while to repeat the experiment; and this was done as far as the supply of soils at hand would permit. The method used was changed somewhat, in that dried blood was used in this instance at the rate of .1 gram for 50 grams of soil. The solution for analysis was obtained by leaching the soil on a filter paper held in a large funnel, until 100 cc of leachings were obtained. In case extracts were turbid, a little calcium nitrate was added to clear the solution. This was done, where necessary, after part of the extract had been analyzed for nitrates. A treated and an untreated portion was used in this experiment, to determine if the unfertilized soil developed soluble manganese. The soils were incubated at laboratory temperature from August 13 to November 20, 1917. The results obtained by this method are to be found in Table X.

TABLE X.—*The Effect of Nitrification of Dried Blood on the Development of Soluble Manganese in Acid Soils.  $\text{NO}_3$  and Mn. in p. p. m. of Air Dry Soil.*

| Soil No.             | Soil untreated |      | Soil, +.1gm dried blood |      |
|----------------------|----------------|------|-------------------------|------|
|                      | $\text{NO}_3$  | Mn   | $\text{NO}_3$           | Mn   |
| 1 <sup>1</sup> ----- | 66.0           | None | 380.0                   | 8.0  |
| 2 <sup>1</sup> ----- | 376.0          | 4.2  | 860.0                   | 25.0 |
| 20 -----             | 80.0           | None | 480.0                   | 13.0 |
| 21 -----             | 160.0          | None | 720.0                   | 63.0 |
| 31 -----             | 120.0          | None | 400.0                   | 5.8  |
| 41 -----             | 100.0          | None | 720.0                   | 43.6 |
| 45 -----             | 75.0           | None | 300.0                   | None |
| 47 -----             | 120.0          | None | 880.0                   | 23.0 |
| 48 -----             | 100.0          | None | 640.0                   | 38.6 |
| 51 -----             | 300.0          | None | 360.0                   | 53.8 |
| 53 -----             | 120.0          | None | 800.0                   | 77.5 |
| 54 -----             | 140.0          | None | 500.0                   | 9.5  |
| 56 -----             | 100.0          | None | 500.0                   | 14.5 |
| 60 -----             | 200.0          | None | 400.0                   | 2.1  |
| 62 -----             | 160.0          | None | 520.0                   | 42.0 |
| 64 -----             | 60.0           | None | 440.0                   | 14.5 |
| 69 -----             | 50.0           | None | 480.0                   | 30.0 |
| 70 -----             | 132.0          | None | 480.0                   | 6.4  |
| 72 -----             | 55.0           | None | 630.0                   | 11.5 |
| 76 -----             | 46.0           | None | 450.0                   | 44.5 |

<sup>1</sup>Sample No. 1 is Plainfield sand, and sample No. 2 is Marshall silt loam, both of which were kindly furnished by E. Truog of the Wisconsin Agricultural Experiment Station.

An inspection of Table X shows clearly that the addition of dried blood caused an increase in the soluble manganese in each of the soils, with the exception of No. 45. The amounts made soluble in soils No. 21, 41, 48, 51, 53, 62, and 76 are probably sufficient to cause serious injury to most plants. Calculating the manganese as nitrate, and assuming the acre foot of soil 6 inches deep to weigh two million pounds, the manganese recovered from several of these soils is equivalent to more than 200 pounds per acre, an amount that has been found by a number of investigators, to be great enough to injure crops. In the unfertilized soils, only the Marshall silt loam from Wisconsin gave any manganese in the extract. The evidence here given seems to warrant the conclusion that the acids developed in the nitrification of dried blood may dissolve manganese in large quantities in the absence of active bases. Further, it appears that sulphate of ammonia may increase the solubility of manganese without increasing the amount of nitrates in a soil. On the other hand, the data show that a very considerable degree of nitrification of the organic matter occurring in soils, does not bring manganese into solution, as indicated by the methods used. Again, when rapid nitrification causes the solution of some manganese, not more than 20 per cent of the nitrates recovered were in the form of manganese nitrate, assuming all of the manganese to be in nitrate form.

#### STUDIES ON SOILS FROM PLOTS 31 AND 32, TIER 4, OF THE PENNSYLVANIA EXPERIMENT STATION

Through the courtesy of Prof. J. W. White, a small quantity of soil was obtained from plots 31 and 32, tier 4, of the rotation experiments at the Pennsylvania Experiment Station. Plot 31 receives 48 pounds of nitrogen and plot 32 receives 72 pounds, in the form of sulphate of ammonia. The acidity of these two soils according to White (21) is roughly proportional to the amount of sulphate of ammonia that has been applied. The soil on plot 32 has become so acid that crops have begun to fail in recent years. To show whether or not soluble manganese would be developed in these two soils, the same method described above was employed, using 100 grams of soil and .1 gram of dried blood and sulphate of ammonia, respectively, per tumbler.

After incubation from August 13 to November 23,

1917, the soil was leached as described above. As soon as the first leaching was completed the containers were replaced by others and a second leaching obtained. The soil was then air dried and again leached. The treatments and the analyses of the extracts are given in Table XI.

TABLE XI.—*The Effect of Dried Blood and Sulphate of Ammonia on the Development of Soluble Manganese in Soils from the Pennsylvania Experiment Station. Mn. and NO<sub>3</sub> in p. p. m. of Air Dry Soil.*

| TREATMENT         | Soil from plot 31 |     |     |                             |     |  | Soil from plot 32 |      |     |                             |       |  |
|-------------------|-------------------|-----|-----|-----------------------------|-----|--|-------------------|------|-----|-----------------------------|-------|--|
|                   | Mn in Leaching    |     |     | NO <sub>3</sub> in Leaching |     |  | Mn in Leaching    |      |     | NO <sub>3</sub> in Leaching |       |  |
|                   | 1                 | 2   | 3   | 1                           | 2   |  | 1                 | 2    | 3   | 1                           | 2     |  |
| Dry checks -----  | 17.0              | 5.4 | 3.2 | 18.0                        | 1.7 |  | 33.5              | 11.0 | 6.2 | 29.0                        | trace |  |
| Dist. water ----- | 12.2              | 2.0 | 1.2 | 140.0                       | 2.2 |  | 54.0              | 13.4 | 7.1 | 210.0                       | 8.2   |  |
| Dried blood ----- | 46.2              | 3.9 | 2.9 | 430.0                       | 2.7 |  | 89.0              | 12.0 | 8.6 | 370.0                       | 6.8   |  |
| Am. sulphate ---  | 45.0              | 4.8 | 2.0 | 160.0                       | 2.0 |  | 115.0             | 14.0 | 6.7 | 110.0                       | 10.0  |  |

In the first leachings, the air dry soil from plot 31 gave up 17 p. p. m. and soil from plot 32, 33.5 p. p. m. of manganese. Incubation of these soils with distilled water for three months resulted in a decrease in the soluble manganese in soil from plot 31, while there was quite an increase in the amount recovered from soil from plot 32. In each soil incubation with dried blood produced approximately 2.5 as much soluble manganese as was found in the dry checks; and very notable increases in the nitrate content. Soil from plot 31 nitrified ammonium sulphate to a certain extent, with an increase in the soluble manganese equal to that produced by dried blood. On the other hand, ammonium sulphate retarded nitrification in the soil from plot 32, but caused an enormous increase in the solubility of the manganese. Qualitative tests showed the presence of traces of iron and small amounts of aluminum in some of the extracts. However, the amount of aluminum present was not nearly as great as the manganese.

The amount of chlorides found in the soil extracts was very small; and of those examined for sulphates, where dried blood was the source of nitrogen, only minute quantities of sulphate were found. The conclusion seems justified, therefore, that the manganese recovered was in the form of nitrate, in the dried blood treated soils; and as nitrate or sulphate

in the soil to which ammonium sulphate was applied. The evidence presented indicates that the addition of certain nitrogenous fertilizers to acid soils from the Pennsylvania plots may increase the infertility of these plots by bringing into solution relatively large quantities of manganese.

In order to study the toxicity of the extracts of the Pennsylvania soils, the following methods were used: Eight hundred gram portions of the soil were weighed out and treated with one gram of dried blood, and 0.8 gram of ammonium sulphate, respectively, and thoroughly mixed. Each portion of soil was then placed in a percolator, the required amount of distilled water added, and incubated at 28°C. from October 12 to December 29, 1917. Each percolator was then leached with distilled water until 1600 cc. had passed through the 800 gms. of soil contained. Samples of the air dry soil were also leached to make possible a comparison of the extracts of the original soil with those of the same soil that had been treated. Pea cultures were set up in the usual way and permitted to grow from Jan. 5 to Jan. 26, 1918. A photograph of all cultures grown in the extract of the soil from plot 32 is shown in Plate VI, fig. 1, and the complete data is presented in Table XII.

TABLE XII.—*The Effect of KOH and CaCO<sub>3</sub> on the Toxicity of Water Extracts of the Soil from Plots 31 and 32, Penn. Exp. Station. Air Dry Weight of Pea Roots and Tops, in Grams.*

| Source of culture medium            | Treatment of culture medium                    | Partial Com-<br>position<br>P. P. M. |      |                 | Average<br>weight of |
|-------------------------------------|------------------------------------------------|--------------------------------------|------|-----------------|----------------------|
|                                     |                                                | Ca                                   | Mn   | NO <sub>3</sub> |                      |
| Tap water                           | ---                                            | ---                                  | ---  | ---             | Roots                |
| Distilled water                     | ---                                            | ---                                  | ---  | ---             | 1769.2486            |
| Extract, plot 31, initial condition | ---                                            | ---                                  | ---  | ---             | 1249.1395            |
| Extract, plot 31, plus dried blood  | ---                                            | ---                                  | 12.0 | 9.5             | 1486.2607            |
| Extract, plot 31, plus dried blood  | ---                                            | 60.2                                 | 22.0 | 200.0           | 1521.2281            |
| Extract, plot 31, plus dried blood  | 1.0 gm. CaCO <sub>3</sub>                      | ---                                  | 22.0 | 200.0           | 1491.1862            |
| Ext. plot 31, plus am. sulphate     | 1.0 gm. CaCO <sub>3</sub> plus CO <sub>2</sub> | ---                                  | 22.0 | 200.0           | 1689.2500            |
| Ext. plot 31, plus am. sulphate     | ---                                            | 77.3                                 | 42.5 | 110.0           | 1596.2180            |
| Ext. plot 31, plus am. sulphate     | ---                                            | ---                                  | 42.5 | 110.0           | 1734.2282            |
| Ext. plot 31, plus am. sulphate     | 1.0 gm. CaCO <sub>3</sub> plus CO <sub>2</sub> | ---                                  | 42.5 | 110.0           | 1725.1946            |
| Extract, plot 32, initial condition | ---                                            | 22.0                                 | 21.0 | 18.0            | 1391.1892            |
| Ext. plot 32, incubated, no fert.   | ---                                            | 36.1                                 | 37.5 | 100.0           | 1150.1990            |
| Ext. plot 32, plus am. sulphate     | 1 cc N/1 KOH                                   | ---                                  | 37.5 | 100.0           | 1860.2610            |
| Ext. plot 32, incubated, no fert.   | 2 cc N/1 KOH                                   | ---                                  | 37.5 | 100.0           | 2033.2569            |
| Ext. plot 32, plus am. sulphate     | ---                                            | 41.4                                 | 42.5 | 53.7            | 1097.3172            |
| Ext. plot 32, plus am. sulphate     | 2 cc N/1 KOH                                   | ---                                  | 42.5 | 52.7            | 2025.2839            |
| Ext. plot 32, plus am. sulphate     | 4 cc N/1 KOH                                   | ---                                  | 42.5 | 53.7            | 1927.3045            |
| Ext. plot 32, plus am. sulphate     | 1.0 gm. CaCO <sub>3</sub>                      | ---                                  | 42.5 | 53.7            | 1967.2499            |
| Ext. plot 32, plus am. sulphate     | 1.0 gm. CaCO <sub>3</sub> plus CO <sub>2</sub> | ---                                  | 42.5 | 53.7            | 2059.2630            |
| Extract, plot 32, 2nd leaching      | ---                                            | ---                                  | ---  | ---             | 1645.2656            |



The soil from plot 31 nitrified dried blood much more efficiently than ammonium sulphate. However, ammonium sulphate caused nearly twice as much manganese to go into solution as did the dried blood. Ammonium sulphate retarded nitrification in the soil from plot 32, but increased the amount of manganese in the solution. Incubation of this soil without fertilizers of any kind, increased the amount of soluble manganese from 21 to 37 p. p. m. of solution.

In every case, the peas grown in the untreated soil extracts showed a tendency to bleach; the untreated extract from plot 32 produced plants that were almost white. Those extracts to which calcium carbonate was added made a good growth of both roots and tops; but even here, bleached leaves were found, and the entire foliage was of a lighter green color than that of plants grown in the solution to which caustic potash had been added. According to McCool (12), such bleaching is a characteristic effect of manganese. Had these cultures received direct sunlight, instead of the subdued light from glazed windows, it is very probable that the injury to the tops would have been much more severe.

As shown in Table XII, the extract of the soil from plot 31 which had been incubated with dried blood contained 22 p. p. m. of Mn., and 200 p. p. m. of  $\text{NO}_3$ . The original air dry soil from plot 32 gave an extract with 21 p. p. m. of Mn., and 18 p. p. m. of  $\text{NO}_3$ . With the same manganese content, these two extracts differed widely in toxicity. Each supported a fair root growth; but the tops of the peas grown in the extract from plot 32 were highly abnormal in development, and were almost white. Since these extracts contained widely different amounts of nitrates, it was thought possible to explain the difference in toxicity on the basis of the difference in calcium content. Therefore, after the cultures were taken down, quantitative calcium determinations were made on these, and on several other untreated extracts. And the less toxic extract with the high nitrate content, was found to contain 60.2 p. p. m. of Ca., while the more toxic extract contained only 22.0 p. p. m. of Ca. Incubated with sulphate of ammonia, soil from plots 31 and 32 gave extracts with identical amounts of manganese. But the extract from plot 31 was not nearly so toxic toward pea roots as was the extract from plot 32. The difference in the calcium content of the two extracts again offers an

explanation as to the cause of the difference in toxicity. These data in a large measure confirm the suggestion that it is the relative amount of soluble manganese, rather than the total, that determines the toxicity of a soil, or of its extract.

Considering in detail the extracts of the soil from plot 32, a photograph of which is given in Plate V, fig. 1, it will be seen that the extract of the original soil produced abnormal, bleached tops, but a fair development of roots. However, the addition of a little caustic potash to this extract removed the toxicity toward both roots and tops. Incubated with sulphate of ammonia, soil from plot 32 gave an extract that was extremely toxic. Here again, the tops were almost white, and made practically no growth. The roots grew but little after being placed in the solutions, lateral root development being almost completely suppressed. The toxicity of this extract was completely removed by the addition of caustic potash. In each case the manganese precipitated from the extracts was left in the tumblers in which the plants grew. By a close inspection of the photograph on Plate VI, fig. 1, the black precipitate may be seen in the bottom of the tumblers, 3, 4, 6, and 7. The precipitated manganese, with roots growing in it, is very clearly shown in the photograph on Plate VI, fig. 2. Insoluble manganese has no toxic effect whatever, since many roots were growing normally, even where several inches of root were embedded in the precipitated manganese. In so far as can be judged by the methods used, it would appear that the infertility of the sour plots in the Pennsylvania rotation experiments owe their infertility, in a large measure, to the presence in the soil solution of relatively large amounts of manganese.

#### DOES SULFOFICATION DEVELOP SOLUBLE MANGANESE?

When sulphur is added to an unsterilized soil and incubated, a part of the sulphur is oxidized to sulfuric acid. The result of such oxidation is to increase the acidity of acid soils. Ames and Boltz (1) found a decided increase in the water soluble acidity of soils to which sulphur had been added. Shedd (16) found that the addition of large amounts of sulphur enormously increased the acidity of the soil, even where lime had been applied at the rate of 4,000 pounds per acre. Where large amounts of sulphur had been added, plants eith-

er failed to germinate, or made but little growth if there was any germination.

In view of the fact that our work indicated an increase in the solubility of manganese due to the use of dried blood or ammonium sulphate, it was thought worth while to study the influence of sulfocation on the development of soluble manganese in acid soils. In this experiment the same methods were used as in the study of the effect of dried blood, 0.1 gm. of sulphur being used to each 100 gms. of air dry soil. The soils were incubated at room temperature from Nov. 16, 1917, to Jan. 30, 1918. They were then leached as previously explained and manganese determinations made. The data so obtained are set forth in Table XIII.

TABLE XIII.—*The Effect of Sulphur on the Development of Soluble Manganese in Acid Soils.*

| Source of Soil                            | Treatment                                 | Mn in p. p. m. of air dry soil |
|-------------------------------------------|-------------------------------------------|--------------------------------|
| Plainfield sand, Wis. -----               | None -----                                | None                           |
| Plainfield sand, Wis. -----               | 0.1 gm. sulphur -----                     | 54.0                           |
| Marshall silt loam, Wis. -----            | None -----                                | trace                          |
| Marshall silt loam, Wis. -----            | 0.1 gm. sulphur -----                     | 54.0                           |
| Plot 31, Penn. Agr. Exp. Sta. --          | None -----                                | 26.0                           |
| Plot 31, Penn. Agr. Exp. Sta. --          | 0.1 gm. sulphur -----                     | 182.0                          |
| Plot 32, Penn. Agr. Exp. Sta. --          | None -----                                | 84.0                           |
| Plot 32, Penn. Agr. Exp. Sta. --          | 0.1 gm. sulphur -----                     | 168.0                          |
| Thomasville, Ala. -----                   | None -----                                | None                           |
| Thomasville, Ala. -----                   | 0.1 gm. sulphur -----                     | 160.0                          |
| Leroy, Ala. -----                         | None -----                                | None                           |
| Leroy, Ala. -----                         | 0.1 gm. sulphur -----                     | 40.0                           |
| Boaz, Ala. -----                          | None -----                                | None                           |
| Boaz, Ala. -----                          | 0.1 gm. sulphur -----                     | 38.0                           |
| Clanton, Ala. -----                       | None -----                                | None                           |
| Clanton, Ala. -----                       | 0.1 gm. sulphur -----                     | 52.0                           |
| Tanner, Ala. -----                        | None -----                                | None                           |
| Tanner, Ala. -----                        | 0.1 gm. sulphur -----                     | 104.0                          |
| Oxford, Ala. -----                        | None -----                                | None                           |
| Oxford, Ala. -----                        | 0.1 gm. sulphur -----                     | 68.0                           |
| Oxford, Ala. -----                        | 0.2 gm. sulphur -----                     | 168.0                          |
| Plot 4, Ala. Exp. Sta. <sup>1</sup> ----- | None -----                                | 3.6                            |
| Plot 4, Ala. Exp. Sta. -----              | 0.1 gm. sulphur -----                     | 33.6                           |
| Plot 4, Ala. Exp. Sta. -----              | 0.2 gm. sulphur -----                     | 39.6                           |
| Plot 4, Ala. Exp. Sta. -----              | 0.1gm. sul. 1gm. CaCO <sub>3</sub> -----  | None                           |
| Plot 8, Ala. Exp. Sta. <sup>2</sup> ----- | None -----                                | None                           |
| Plot 8, Ala. Exp. Sta. -----              | 0.1 gm. sulphur -----                     | 28.0                           |
| Plot 8, Ala. Exp. Sta. -----              | 0.2 gm. sulphur -----                     | 54.0                           |
| Plot 8, Ala. Exp. Sta. -----              | 0.1gm. sul., 1gm. CaCO <sub>3</sub> ----- | None                           |

<sup>1</sup>From source of nitrogen test.

<sup>2</sup>From rotation experiments.

All of the soil extracts were tested for sulphates, and it was found that each soil to which sulphur was added contained much more sulphates than the untreated soil. However, quantitative determinations were not made. The oxidation of sulphur increased the amount of soluble manganese in each of the soils used; and in several the amount made soluble was relatively large. In both of the soils from Pennsylvania and in three of the soils from Alabama, above 100 p. p. m. of manganese were made soluble. The smallest amount found in the treated soils was 28 p. p. m. Calcium carbonate added at the rate of 1 per cent completely prevented the solution of manganese. The results indicate that soils in need of sulphur fertilization should be well limed, unless already supplied with lime, if injury from sulphur application is to be avoided. Further, it is believed that these results explain the sterility of Shedd's soil to which large amounts of sulphur were applied. Manganese, aluminum, or iron, in the form of sulphate, very probably cause sterility, rather than free sulfuric acid.

#### THE TOXICITY OF FIELD SOILS TO WHICH DIFFERENT NITROGENOUS FERTILIZERS HAVE BEEN APPLIED

As stated in the introduction, 16 plots on the Alabama Experiment Station Farm have been devoted to a field study of the rate of nitrification of dried blood, cottonseed meal, and calcium cyanamid, beginning in the spring of 1913. The area occupied by these plots is very uniform, and is nearly level. The surface soil is very sandy and has a low water capacity. The subsoil is a yellow sandy clay with a much higher water capacity than the surface soil. Soluble salts are very readily lost from this soil by leaching, as shown by unpublished results.

The fertilizers given these plots are in sufficient amounts to furnish nitrogen at the rate of 77 pounds per acre. All fertilizer has been applied broadcast, and either disked or plowed in. Since 1915, applications have been made in both spring and fall.

Each crop is grown continuously on the same set of plots. With the exception of the first year, one-half of each plot has been fallowed both winter and summer. A winter cover crop of oats has been planted on the cropped ends of all plots most of the years.



All of the summer crops made a fair response to the nitrogenous fertilizers during the years 1913-15. The summer of 1916 was so extremely unfavorable that little was made on any of the plots.

During the late winter and early spring of 1916, it was noticed that a brown crust had formed on the surface of some of the highly fertilized plots, which crust contained an enormous amount of nitrates. Pot experiments previously described indicated that this brown crusted soil contained some material that was toxic to plants. In order to get as much information as possible on the cause of this toxicity, the plots were carefully planted in 1917, both the fallowed and the cropped ends being planted. The spring was comparatively dry thus affording conditions favorable for salt accumulation.

At the end of the growing season all of the crops were harvested and weighed green. The corn and sorghum were cut near the ground, while the cotton and cow peas were pulled, both root and top being weighed. The yields obtained are set forth in Table XIV.

TABLE XIV.—*Yield of Crops from Plots Treated with Different Forms of Nitrogenous Fertilizers. Green Weight of Crops in Pounds.*

| Treatment of Plot      | Crops              |       |      |        |
|------------------------|--------------------|-------|------|--------|
|                        | Sorghum            | Corn  | Peas | Cotton |
| Dried blood -----      | 12663              | 11718 | 5481 | 126    |
| Cotton seed meal ----- | 16821 <sup>1</sup> | 17693 | 9576 | 2520   |
| None -----             | 12663              | 5733  | 5985 | 1764   |
| Calcium cyanamid ----- | 17514 <sup>1</sup> | 15876 | 8631 | 4662   |

<sup>1</sup>These sections of the sorghum plot received dried blood. In 1913, only the first section was fertilized. The entire plot was unfertilized in the fall of 1916.

Considering the effect of the different forms of nitrogen, it will be seen that dried blood produced the poorest yields with each crop. The highest yield of corn and peas was obtained from the plot treated with cotton seed meal, while cotton yielded best on the plot fertilized with calcium cyanamid. The brown surface crust before mentioned has never been noted on the unfertilized plot, nor on the plots treated with calcium cyanamid. The nitrate content of these plots is usually much lower than that of the plots receiving cotton seed meal or dried blood. Of the crops fertilized with cotton seed meal, cotton was the only one that was



seriously injured in the field. Each crop fertilized with dried blood suffered very seriously from some cause. The damage on the dried blood sections was much greater on the ends that had been in fallow for several years, than on the ends that had been continuously cropped, with the exception of the plot in cotton, in which case the entire plot failed. The condition of each crop on the end of the plots previously fallowed and previously cropped, is clearly shown in the photographs on Plates VII, VIII and IX. A possible explanation of the different yielding powers of the fallowed and the cropped ends of the plots is that toxic salts accumulated in the fallowed section. At times during previous seasons, the fallowed plots frequently accumulated more than 100 p. p. m. of nitrates, while the other end of the same plot, carrying a crop, usually had less than 10 p. p. m. at the same time. It should be stated, however, that such differences usually disappeared with the coming of heavy winter rains. Even in such instances, it is possible that the readily soluble salts may have been, in part at least, brought back to the surface soil in the capillary water during the dry weather of spring.

It is difficult to explain the much greater injury to crops on the plots fertilized with dried blood than on those where cotton seed meal is the source of nitrogen. The nitrate content of the plots to which cotton seed meal is added has been, usually, slightly higher than in the dried blood treated plots. It has been suggested that a part of the nitric acid developed through the nitrification of the cotton seed meal may be neutralized by the calcium and potassium compounds in the meal itself, and hence less manganese is rendered soluble.

Examination of the roots of plants which were making poor growth showed that the roots were brown or nearly black, and in many cases, practically dead. Cotton plants shed most of their leaves, and finally most of them died outright. The leaves of sorghum and corn seemed to be affected alike. The tips and margins of the leaves turned yellow and usually died. So many of the sorghum plants died that by summer, the stand was very poor. The corn plants had a purplish color, similar to that described by Kelley (19).

In the fall of 1917 the first tier of plots in this section was prepared as usual and planted on October 20. One or two rows of the following crops were planted

across each section: Rye, wheat, oats, crimson clover, bur clover, narrow leaf vetch, hairy vetch, and rape. On December 24, 1917, specimen plants from the plots fertilized with dried blood and with calcium cyanamid were dug with a hand trowel, placed in covered jars, and taken to the laboratory to be photographed. The plants were taken up and handled as nearly alike as possible. The condition of the root and top is clearly shown in Plates X, XI and XII. The roots of all plants fertilized with dried blood were unhealthy, poorly developed, and appeared to be practically dead. The absence of root hairs is shown by the dearth of soil adhering to the roots. The few roots produced by bur clover were all dead at the time the plants were photographed. Rape, crimson and bur clover had been so severely injured that scarcely enough plants could be found for photographic purposes; while wheat, rye, oats, and the vetches were still living, but making no growth.

An examination of the plants in the plot to which cotton seed meal was applied showed that there was some injury to plant roots in this plot, but not nearly so much injury as was found on the plot fertilized with dried blood.

Water soluble manganese has been recovered from the plots fertilized with cotton seed meal or dried blood, but none has been found in the plots treated with calcium cyanamid. Apparently calcium cyanamid has a sufficient basic tendency to prevent the development of soluble manganese in this soil. The fact that the lime requirement of the plots fertilized with dried blood and with calcium cyanamid is 2568 and 856 pounds per acre, respectively, supports this view.

#### DISCUSSION

It is believed that the work here presented offers further explanation of the cause of infertility of acid soils. Regarded in a broad way, it may be stated that the results emphasize the importance of sufficient active bases in the soil to prevent the solution of such compounds as manganese and possible aluminum, iron, etc. This view is substantiated by the fact that soil extracts which are toxic, apparently, because of the presence of soluble manganese, may be made non-toxic by the addition of either calcium, sodium, or potassium hydroxide. Such toxic extracts may be greatly improved by the precipitation of only a part of the soluble

manganese, the corresponding salts of the added bases probably serving as an antidote to the salts of manganese remaining in solution. According to this view, non-productive acid soils may owe their infertility to the presence in the soil solution of salts of certain bases which are injurious to plant growth, rather than to the actual acidity of the soil. Support for this view may be found from the fact that corn, cotton, cow peas, velvet beans, soy beans, peanuts, and sorghum have been grown on a set of plots on the Alabama Experiment Station Farm, the soil of which has nearly twice as high a lime requirement as have the plots from which most of our soil extracts were obtained for the work here given. The more acid soil receives moderate fertilization and is productive, while the less acid plots are heavily fertilized with nitrogenous fertilizers, and are rapidly becoming non-productive. In other words, productivity seems to be more dependent upon the nature of the salts in the soil solution, than on the actual acidity of the soil. (a) In this connection, it would be very interesting to know the solubility of the manganese in the soil solution of the variously treated plots of the rotation experiment at the Pennsylvania Station. For the soil on these plots, White has attempted to set an acidity limit beyond which clover fails. Is it actual acidity, or is it soluble manganese that prevents the growth of clover, after the lime require-

(a) Since the completion of this manuscript, a paper by B. L. Hartwell and F. R. Pember (*Jour. Am. Soc. Agr.*, v. 10, No. 1) has come to hand in which a very similar view has been advanced, based on studies on soluble aluminum in acid soils of Rhode Island. These writers state that "A moist acid soil upon which most kinds of plants were unable to exist was kept intimately mixed for about two weeks with acid phosphate added at the extraordinary rate of 28 tons per acre, after which lettuce was planted. This crop could not exist on the unphosphated soil supplied only with nutrients, but the soil treated with acid phosphate produced a maximum crop, even more than when lime replaced the phosphate. It was shown that for a considerable time at least, the large amount of acid phosphate greatly increased the acidity, and yet a crop which usually responds markedly to liming had made its maximum growth on a very acid soil without the addition of any lime. The solubility of the aluminum in dilute acetic and carbonic acids had been markedly reduced by the phosphate, just as it doubtless would be by lime or by a mixture of the two."

"Determinations of the amount of what may be called active aluminum may prove to be as desirable as acidity determinations, and the lime requirement of a soil may be due to the need for lime to precipitate toxic aluminum quite as much as to neutralize acidity."

ment approximates a certain amount per acre? Again, does sorrel invade acid soils because it grows well under such conditions? White (22) has shown that lime greatly benefits this plant, and that it is found on the very sour plots 32 because other plants failed and there is no competition. Since sorrel is not an acid loving plant, but still grows where clover and other crops fail, apparently, it is the tolerance of manganese, more than the tolerance of acidity which permits this plant to grow under such conditions.

In his discussion of the variations in yields from the acid plots at Pennsylvania, White (21) says the variations may be due to "increasing amounts of organic acids which in the absence of sufficient basic material accumulate from year to year and exert an increasing 'toxic' effect on plant growth. The resultant effect may be physical, chemical, physiological, or bacteriological." Studies on soils from Pennsylvania and from Alabama indicate strongly that the toxicity of the soils used is due chiefly to soluble manganese, with possibly aluminum playing a small part. Precipitation of the manganese from the water extract of these soils is all that is necessary to make such extracts very satisfactory mediums for plant growth. Further, there is little indication that the toxicity of the Alabama soil extracts is due to any form of organic matter. Extracts from our soils have been ashed in several experiments with little or no indication of benefit, except where the ash was taken up with tap water. Nor has carbon black effected any marked improvement in such extracts. Boiling in the open, or under a reflux condenser failed to reduce the toxicity. The distillate from the soil extracts proves to be as good medium for plant growth as ordinary distilled water. These tests are deemed to be sufficient to show that the toxic body is inorganic, rather than organic. Of the unusual inorganic elements found, manganese was present in greatest quantity, and is very probably the chief cause of toxicity.

The data presented on the previous pages puts special emphasis on the toxicity of manganese soluble in the soil solution of acid soils. However, the possibility



of the occurrence of soluble aluminum and iron under such conditions has not been disregarded, since it has been shown that under certain conditions quite appreciable amounts of aluminum, with usually less amounts of iron occur in the water extracts of acid soils. Connor et al (3) have shown that acid soils of the Kankakee region of Indiana contained relatively large amounts of water soluble aluminum, and small amounts of iron. The soils studied appeared to support a vigorous nitrification, with aluminum as the base, in part at least, uniting with the nitric acid formed. The aluminum nitrate thus produced was thought to account for the barrenness of the soils in question. A water extract of these soils was found to be about as toxic as a solution carrying aluminum nitrate and nutrient salts to approximate the composition of the soil extract. The addition of various chemicals which would precipitate the aluminum, removed the toxicity of such extracts.

Ruprecht and Morse (15) found considerable amounts of water soluble iron and aluminum in soil that had been continuously fertilized with ammonium sulphate; further, treatment of the soil with ammonium sulphate increased the solubility of these compounds, showing that use of this nitrogenous fertilizer on acid soils may cause injury to crops through the solution of such elements even though no nitrification takes place.

In the writer's work on the soils from the Alabama Experiment Station Farm, not more than traces of iron was found; and in many instances, only traces of aluminum were present. One of the very concentrated extracts used early in the work had less than one-tenth as much soluble aluminum as manganese; while a recent extract contained 15.8 p. p. m. of aluminum and 80 p. p. m. of manganese. The extracts from plot 32 of the Pennsylvania Experiment Station contained mere traces of iron, and but little more than traces of aluminum. On the other hand, under various treatments this soil has been found to contain from 75 to more than 100 p. p. m. water soluble manganese. Since normal soils have been shown by Robinson (14) to contain very much more aluminum than manganese, it would appear that the manganese compounds found in soils are more readily soluble than aluminum. It is conceivable, however, that in time the small amounts of



manganese may be exhausted,\* and that soluble aluminum and iron be found in soils where now, chiefly manganese goes into solution.

The occurrence of soluble manganese in a soil extract is a strong indication of acidity. But not all acid soils contain soluble manganese. From our work, it appears that rapid nitrification, or the use of a fertilizer which is acid in nature, are the chief causes for the solubility of this element. Slow nitrification of the relatively inert soil organic matter causes but little development of soluble manganese, as shown by data in Table IX. In neutral soils, soluble manganese is rarely found; and under basic conditions, the writer has never found a trace of this element soluble in water. Soluble manganese added to a very acid soil may be quite largely removed by leaching, even after standing for some days. But if calcium carbonate be added to an acid soil, soluble manganese applied is rapidly removed from solution, calcium being found instead. An acid soil so treated in our laboratory contained but a trace of soluble manganese after six days, and none after thirteen days.

The field work of Skinner and Reid (19) is interesting in this connection. On acid soil of the Arlington Farm, an application of 50 pounds per acre of manganese sulphate caused decreased yields of wheat, corn, cowpeas and potatoes; with rye, variable results were obtained. After continuing the experiment for five years, systematic liming of the soil was begun. When sufficient lime had been applied to completely counteract the acidity, each crop except potatoes yielded best on the manganese treated area. In all probability, the decreased yields attributable to the use of manganese sulphate before liming, were due to the fact that this compound remained unchanged in the acid soil, and proved toxic to the crops grown; on the other hand, it is very doubtful if the increased yields obtained after liming should be attributed to manganese sulphate as such. With the establishment of basic conditions, the soluble manganese added would very likely be precipitated in a relatively insoluble condi-

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\*As an average of determinations made on duplicate samples of soil from the plots used in our field work, there were 262.5 p. p. m. of Mn., and 51.3 p. p. m. of Ca., soluble in hydrochloric acid, the digestion being made according to the A. O. A. C. method.

tion, with the formation of a corresponding amount of calcium sulphate. The increased productiveness then, may have been due to the precipitated manganese compounds, or to the stimulating action of calcium sulphate, or to the sulphur applied. In discussing these results, Skinner and Reid state that "The action of manganese in decreasing the oxidation in the soil while acid is in harmony with the decreased yield, and its action in increasing the oxidation of the neutralized soil is in harmony with the increased yield. The action of manganese in the acid soil was probably to stimulate the life processes in the soil, acting on the organic matter in such a way as to produce changes which resulted in a lessened crop-producing power, while its action in the neutralized soil was such as to stimulate oxidation and other biological processes, acting on the organic soil constituents and producing changes favorable to the growing plants."

Skinner and Reid's view as to increased oxidation due to manganese sulphate applied to a basic soil is substantiated by the work of Greaves (5) who, working with a soil which was clearly basic from the analysis given, found that moderate amounts of manganese sulphate stimulate ammonification. Brown (2) has published the results of similar studies, with results similar to those obtained by Greaves, with respect to ammonification. However, the data obtained by Brown in his studies on nitrification would seem to indicate that his soil was acid, since there was little or no nitrification of ammonium sulphate in four weeks.

In discussing the peculiar soils of Hawaii, Kelley (9) states that "In Hawaii the growth of certain crops is enormously influenced by the mere burning of small accumulations of brush and undergrowths of Guava and lantana. The effect on cotton on the uplands of Oahu produced by these small fires may represent the difference between success and failure. The color and vigor of the crop on these small areas dotted here and there over a field attract attention. Other crops are affected similarly." Again he says "A field plowed for the first time, although the soil be thoroughly pulverized and reduced to a state of fine tilth, usually will not support plant growth satisfactorily. The farmers of Hawaii have found it necessary to areate newly plowed lands for a period of several months before planting the first crop. It has been observed, however, that excellent growth of crops is obtained on the small

spots where brush was burned and without the continued areation above referred to. Heat, therefore, seems to accomplish in the soil effects similar to those brought about by areation. The application of fertilizers produces no such effects." Since heating by burning brush on Hawaiian soils seemed to accomplish the same results as aeration, Kelley made a study of the effect of heating on the solubility of the constituents of soils; and found that in most soils, heating increased the amount of soluble manganese. Also it is of special interest to note his results on the unheated soils. Working with both normal and abnormal types, he reports water soluble manganese, iron, and aluminum in each of the unheated soils.

While no definite statement was made as to the acidity of the soils used, it is evident that each was acid, else these water soluble compounds were not likely to have been found. In all probability, water soluble iron, aluminum, and manganese found in these soils would be sufficient to account for poor plant growth. Kelley states that his samples No. 416 and 417 are representative of a type of soil abundant in the islands. Soil No. 416 was taken from cultivated land, and No. 417 from a near-by sod. Since these sod lands are non-productive when first put under cultivation, it is interesting to note that much more manganese and iron, and approximately equal amounts of aluminum were recovered from the sod land. The point is stressed that cultivation and aeration reduce the solubility of manganese. With regard to productivity, aeration and heating by the burning of brush seem to accomplish the same beneficial results. The results reported above suggest that the increased fertility found where brush was burned on these soils was due to the alkaline ash which would tend to precipitate manganese, iron, and aluminum, rather than to any direct effect of the heating.

From ammonification and nitrification studies on these soils Kelley (11) concludes that while both the cultivated and the uncultivated support ammonification, only the cultivated soils support a vigorous nitrification.

Kelley says "Some of the inert virgin soils appear to contain soluble substances which inhibit nitrification. Sterilization in the autoclave affected both cultivated and uncultivated soil in such way as to render them practically equal in regard to subsequent ammonification and brought about conditions toxic to nitrifica-

tion in each instance; similar effects were produced by heating to still higher temperatures."

Working with soils from the Pennsylvania plots, Given (6) found at the end of 7 days, that the acid soil from plot 32 had produced the greatest amount of ammonia from dried blood. This result was confirmed by repeated experiments. Further studies showed the soil from plot 32 incapable of supporting more than a very feeble nitrification.

White (23) has shown by laboratory studies on the acid soils from the Pennsylvania plots that nitrification of organic substances proceeds at a very slow rate, and that ammonium sulphate is not at all nitrified.

Both Greaves (5) and Brown (2) have shown that ammonification may proceed after the addition of considerable amounts of manganese salts to soils; but Brown's work indicates that the nitrifying organisms are rather sensitive to manganese compounds. In view of the fact that soluble manganese has been found in the soil from Pennsylvania; and manganese, aluminum, and iron in the Hawaiian soils, it seems probable that these compounds in solution may be responsible, in a large measure, for the reduced, or inhibited, nitrification in these soils. This view is not necessarily in conflict with the observations that nitrification does take place in acid field soils carrying a large amount of such elements in solution. In times of drought, the writer has often noted that there was a large accumulation at the surface of the salts contained in soils. At times, nearly the entire nitrate and soluble manganese content of our plot soil has been found in the top inch of soil. To substantiate this view the following is given. In November, 1917, the surface soil from about 5 square feet was scraped from one plot, to a depth of about one-half inch. A water extract of this soil contained 200 p. p. m. of manganese, and 1200 p. p. m. of nitrates. Another sample taken from this area, after the first had been removed, gave an extract with 10 p. p. m. of manganese, and 225 p. p. m. nitrates. Pea cultures grown in these extracts produced .064 and .091 grams of roots, and .164 and .314 grams of tops, respectively.

White presents data showing that similar conditions may obtain in the soil studied by him. During these periods of dry weather, when the salts are largely concentrated at the surface, nitrification may proceed in the deeper layers of the soil; again, with the coming



of a rain, these salts are largely washed down into the deeper layers of the soil, to be again returned to the surface, with the return of dry weather. In laboratory work, where the water content is kept nearly constant, there is little chance for this movement of the salt into zones, and hence, retarded, or even inhibited nitrification results.

While the data given in Tables IX and X show that incubating acid soils with either dried blood or sulphate of ammonia tends to bring manganese into solution, it should be remembered that our soils contained initially, but little soluble manganese. It is not surprising, therefore, that dried blood was nitrified to a considerable extent. On the other hand, several of the soils used failed to nitrify ammonium sulphate. It is probable that manganese brought into solution by this compound, acted as the agent inhibitory to nitrification.

To make a practical application, our work indicates that unfertilized acid soils supporting a slow rate of nitrification, develop but little soluble manganese. On the other hand, if such soils be liberally fertilized with nitrogenous fertilizers, the acids produced therefrom may bring into solution sufficient quantities of manganese to cause serious injury to crop plants. The use of lime in connection with high fertilization becomes imperative, then, if full benefit is to be derived from such fertilization. Whether or not plowing under of large crops of leguminous plants would produce results similar to those obtained with certain fertilizers, is a point that cannot be answered at present.

#### SUMMARY

1. Acid soil on the Alabama Experiment Station Farm has been shown to be injured by the use of dried blood as a fertilizer. It is indicated that cotton seed meal may also cause injury in time; as yet, little injury has resulted from its use.

2. In pot experiments, dried blood and ammonium sulphate produced almost complete sterility in two different soils from the Experiment Station Farm. Lime added to these soils not only prevented injury, but promoted a very vigorous plant growth.

3. Soil which has been made highly unproductive by heavy applications of dried blood, still supports nitrification under field conditions.

4. The infertility of this soil is attributed to the pres-



ence of manganese in the soil solution, rather than to organic toxic bodies.

5. When dried blood is the source of nitrogen, soluble manganese is believed to be due to the action of nitric acid developed by nitrification.

6. When ammonium sulphate is the source of nitrogen, nitrification is apparently unnecessary in order to increase the amount of soluble manganese in acid soils.

7. Reduced growth appears to be due chiefly to the injury to plant roots, from the direct action of manganese, rather than to reduced or altered oxidation of soil organic matter.

8. A part of the injury may also be due to the effect of manganese on the foliage. Plants with bleached leaves are frequently found in both soil and water cultures when soluble manganese is present.

9. Relatively large amounts of manganese were recovered from the soil obtained from the Pennsylvania Experiment Station. Water extracts of this soil were highly toxic to seedling plants.

10. When the manganese was precipitated from these extracts they supported a vigorous plant growth.

11. Apparently, the relative amount of soluble manganese is of more importance, within certain limits, than is the total amount. The presence of considerable amounts of calcium salts in an extract reduces the toxicity of manganese.

12. Precipitation of a part of the manganese by means of bases is much more effective in reducing toxicity than is dilution. Calcium, sodium, and potassium hydroxides were found to be very effective when used in this way.

13. A large number of acid soils from Alabama contained soluble manganese, after incubation with dried blood or ammonium sulphate. Soluble manganese has not been found in any of the basic soils, or in any of the acid soils which had been thoroughly limed.

14. The products of sulfonation appear to be very effective in dissolving manganese in acid soils.

15. It is believed that this work throws light on the conflicting results obtained by different workers who have used manganese as a fertilizer. Manganese salts applied to basic soils would rapidly be changed, the manganese going out of solution. When applied to acid soils, the manganese salt would persist as such, and heavy applications would likely cause injury.

16. Work on several phases of this subject is being continued.

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### PLATE I.

Fig. 1.—Sorghum grown in soil with a high content of  $\text{NO}_3$  and Mn.

- (1) Untreated.
- (2) Limed.
- (3) Leached.
- (4) Leached and,  $\text{NO}_3$  equivalent returned as  $\text{NaNO}_3$ .

Fig. 2.—Sorghum grown in water extract of soil with a high content of  $\text{NO}_3$  and Mn.

- (1) Distilled water.
- (2) Soil extract diluted 50 per cent, precipitated with  $\text{NaOH}$ .
- (3) Soil extract diluted 75 per cent, precipitated with  $\text{NaOH}$ .
- (4) Distillate of soil extract diluted 50 per cent.
- (5) Non-volatile part of extract diluted 50 per cent.
- (6) Soil extract treated with carbon black, diluted 50 per cent.
- (7) Soil extract evaporated, ignited, dissolved, diluted 50 per cent.
- (8) Distilled water treated with carbon black.
- (9) Soil extract diluted 50 per cent.
- (10) Soil extract diluted 75 per cent.





Fig. 1

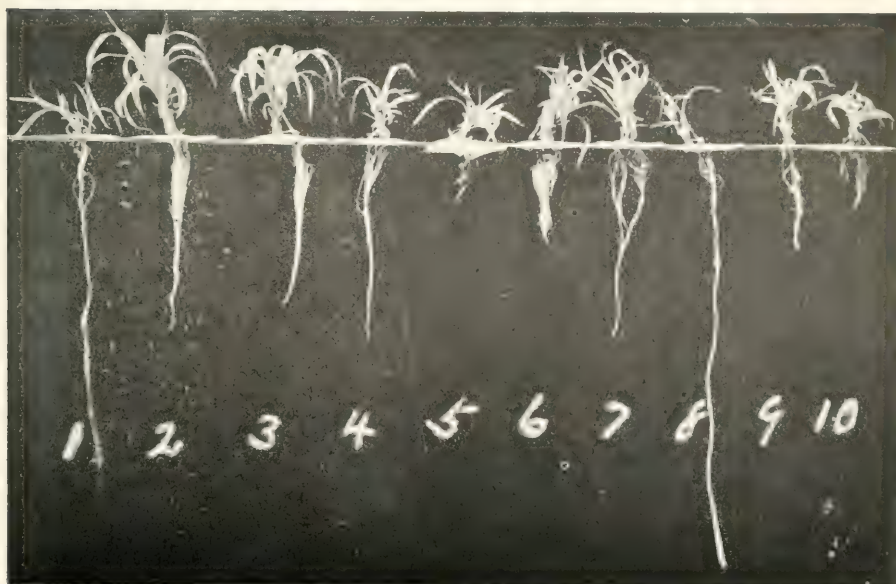


Fig. 2

PLATE II

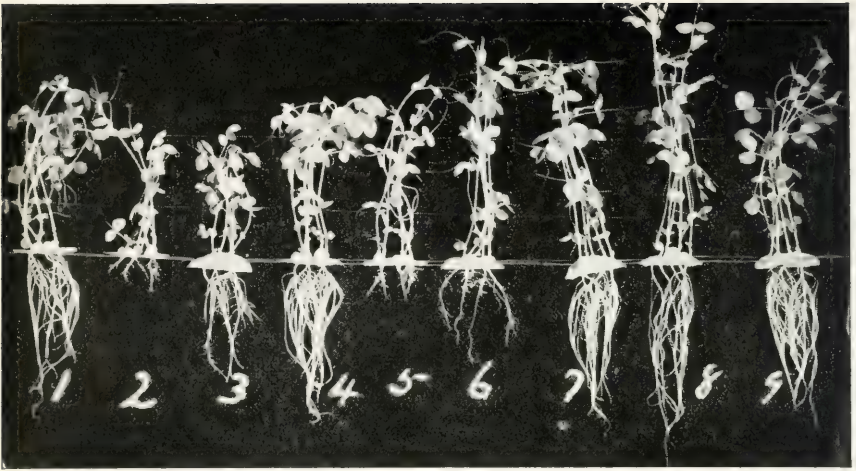


Fig. 1



Fig. 2

## PLATE II.

Peas and sorghum grown in water extract of soil scraped from the surface of plot C1, which plot was very infertile due to the application of dried blood. The extract contained a large amount of nitrates and soluble manganese.

Treatment for figs. 1 and 2:

- (1) Tap water.
- (2) Soil extract untreated.
- (3) Distillate of soil extract.
- (4) Non volatile part of soil extract.
- (5) Soil extract treated with carbon black.
- (6) Soil extract with  $\text{CaCl}_2$  to make a N/20 solution.
- (7) Soil extract precipitated with  $\text{Ca (OH)}_2$ .
- (8) Soil extract evaporated, ignited, dissolved in  $\text{HCl}$ , and neutralized.
- (9) Soil extract, Second leaching.

### PLATE III.

Peas and sorghum grown in water extract of soil scraped from area fertilized with dried blood. The extract contained manganese equivalent to 203 p. p. m. of manganese sulphate.

Treatments for figs. 1 and 2:

- (1) Tap water.
- (2) Distilled water.
- (3) Soil extract untreated.
- (4) Distillate from soil extract.
- (5) Soil extract concentrated, made to volume with distilled water.
- (6) Soil extract concentrated, made to volume with tap water.
- (7) Soil extract ashed, dissolved, made to volume with distilled water.
- (8) Soil extract ashed, dissolved, made to volume with tap water.
- (9) Soil extract treated with two gms. calcium carbonate per liter.



Fig. 1



Fig. 2



PLATE IV



Fig. 1



Fig. 2

#### PLATE IV.

Peas grown in soil extract containing 15.8 p. p. m. of Al., and 90.0 p. p. m. of Mn.

Fig. 1.—

- (1) Tap water.
- (2) Distilled water.
- (3) Soil extract untreated.
- (4) Soil extract plus 0.6 cc N/1 NaOH.
- (5) Soil extract plus 1.2 cc N/1 NaOH.
- (6) Soil extract plus 1.8 cc N/1 NaOH.
- (7) Soil extract plus 2.4 cc N/1 NaOH.
- (8) Soil extract plus 3.0 cc N/1 NaOH.
- (9) Soil extract, second leaching.

Fig. 2.—

- (1) As in fig. 1.
- (2) As in fig. 1.
- (3) As in fig. 1.
- (10) Soil extract 75 per cent, distilled water 25 per cent.
- (11) Soil extract 50 per cent, distilled water 50 per cent.
- (12) Soil extract 25 per cent, distilled water 75 per cent.
- (13) Soil extract, second leaching, as (9) in fig. 1.

## PLATE V.

Fig. 1.—Soil from nitrification plots.

- (1) Untreated.
- (2) Limed.
- (3) Ammonium sulfate, 4.3 grams.
- (4) Ammonium sulfate, 4.3 grams, limed.
- (5) Dried blood, 7.0 grams.
- (6) Dried blood, 7.0 grams, limed.

Fig. 2.—Soil from plot 4, source of nitrogen test.

- (1) Untreated.
- (2) Limed.
- (3) Ammonium sulfate, 4.3 grams.
- (4) Ammonium sulfate, 4.3 grams, limed.
- (5) Dried blood, 7.0 grams.
- (6) Dried blood, 7.0 grams, limed.



Fig. 1



Fig. 2

PLATE VI



Fig. 1



Fig. 2



## PLATE VI.

Fig. 1.—Peas grown in extract of soil from plot 32, Pennsylvania rotation experiments.

- (1) Extract plot 32, original condition.
- (2) Extract plot 32, incubated without fertilizer.
- (3) As (2), plus 1 cc N/1 KOH.
- (4) As (2), plus 2 cc N/1 KOH.
- (5) Extract plot 32, incubated with ammonium sulphate.
- (6) As (5), plus 2 cc N/1 KOH.
- (7) As (5), plus 4 cc N/1 KOH.
- (8) As (5), plus 1 gram  $\text{CaCO}_3$ .
- (9) As (5), plus 1 gram  $\text{CaCO}_3$ , plus  $\text{CO}_2$ .
- (10) Extract plot 32, second leaching.

Fig. 2.—Cultures (5) and (7), fig. 1.

On left, untreated extract.

On right, extract plus 4 ccN/1 KOH per 500 cc extract. Note the extensive root development, and the precipitated manganese in the bottom of the tumbler.

PLATE VII.

Fig. 1.—Corn growing on plot fertilized with dried blood, nitrification plots.

Fig. 2.—Corn growing on plot not fertilized. The photographs in fig. 1 and fig. 2 were taken on areas not more than 40 feet apart.



Fig. 1



Fig. 2

PLATE VIII



Fig. 1



Fig. 2

#### PLATE VIII.

Fig. 1.—In the foreground, cotton on the plot fertilized with dried blood. In the background, cotton on the plot fertilized with cotton seed meal. Cotton was the only crop that was notably injured on the plots fertilized with cotton seed meal.

Fig.—Cotton growing on the unfertilized plot. Note that it is making a better growth than on the plots fertilized with dried blood or cotton seed meal.



#### PLATE IX.

Fig. 1.—Sorghum, corn, and cowpeas growing on the areas fertilized with dried blood.

In right foreground, sorghum on end of plot previously in crops. On left, sorghum on end of plot previously in fallow.

In right middle ground, corn on end of plot previously in crops. On left, corn on end of plot previously in fallow.

In far background, peas on end of plot previously in crops; on left, peas on end of plot previously in fallow.

Fig. 2.—

In the foreground, a near view of the peas shown in fig. 1. In the background, the cotton plot is shown. Note that the entire plot is bare, with the exception of a few scattered, badly stunted plants.



Fig. 1



Fig. 2

PLATE X



# PLATE X.

Fig. 1.—Showing a comparison of plants taken from field plots fertilized with calcium cyanamid and with dried blood.

- (1) Rape from plot fertilized with calcium cyanamid.
- (2) Rape from plot fertilized with dried blood.
- (3) Bur clover from plot fertilized with calcium cyanamid.
- (4) Bur clover from plot fertilized with dried blood.
- (5) Crimson clover from plot fertilized with calcium cyanamid.
- (6) Crimson clover from plot fertilized with dried blood.
- (7) Hairy vetch from plot fertilized with calcium cyanamid.
- (8) Hairy vetch from plot fertilized with dried blood.

# PLATE XI.

Fig. 1.—Showing a comparison of plants grown on field plots fertilized with calcium cyanamid and with dried blood.

(1) Narrow leaf vetch grown on plot fertilized with calcium cyanamid.

(2) Narrow leaf vetch grown on plot fertilized with dried blood.

(3) Wheat grown on plot fertilized with calcium cyanamid.

(4) Wheat grown on plot fertilized with dried blood.



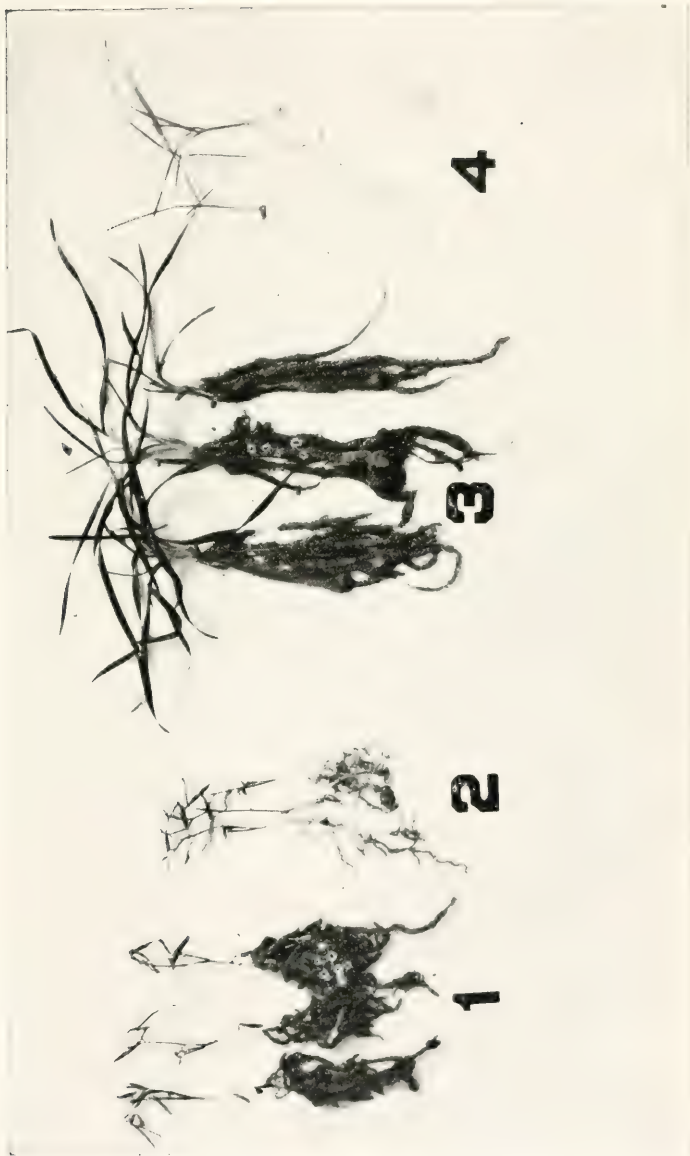




PLATE XII.

Fig. 1.—Showing a comparison of plants grown on field plots fertilized with calcium cyanamid and dried blood.

- (1) Oats from plot fertilized with calcium cyanamid.
- (2) Oats from plot fertilized with dried blood.
- (3) Rye from plot fertilized with calcium cyanamid.
- (4) Rye from plot fertilized with dried blood.









**BULLETIN No. 202**

**JUNE, 1918**

**ALABAMA**  
**Agricultural Experiment Station**

OF THE

**Alabama Polytechnic Institute**

**AUBURN**

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**Growing Soy Beans in Alabama**

A POPULAR EDITION OF No. 203

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By  
**E. F. CAUTHEN**

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# GROWING SOY BEANS IN ALABAMA

By

E. F. CAUTHEN

Associate Agriculturist

---

The soy bean is an erect leguminous plant introduced from Asia. In China and Japan it is grown extensively and used for human food, soil improvement, forage and commercial purposes.

The acreage of soy beans in Alabama is increasing rapidly. The livestock farmers and feeders desire crops that can partly take the place of corn, cottonseed meal and other expensive feeds. They are finding that the soy bean makes a valuable substitute in the feeding of horses and cattle and swine; that its hay is nutritious and liked by stock; and that the crop can be harvested cheaply.

## USES

Soy beans are rich in protein and make a good pasture for growing hogs, which graze on the young and tender leaves, and later feed on the ripened beans. Pasture experiments at Auburn show that pork was made from the feeding of a two-third corn ration and soy bean pasture at a cost of only \$2.74 per hundred pounds.\*

The value of the soy bean for soil improvement should not be overlooked. Being a legume it gathers atmospheric nitrogen and puts it in the soil for any succeeding crop. In addition to being a nitrogen gatherer, it improves the physical condition of the soil rapidly. Experiments made at Auburn in 1911 and 1914 show that cotton, when planted after corn and after soy beans drilled, from which only the seed was harvested, the soy bean land made an average increase over the corn land of 318 pounds of seed cotton per acre. If the seed cotton was reckoned at 4 cents per pound, the fertilizing value of the soy bean stubble and straw would be worth \$12.72 per acre. In another test where the soy bean land and corn land were planted in fall oats, the increase in yield of oats due to the fertilizing value of the soy bean stubble was 173 per cent over the corn land.

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\*Page 63, Bulletin 143, Alabama Experiment Station.

## FERTILIZER AND CULTURE

The soy bean can be grown on almost any kind of soil in Alabama. Any soil that will grow good crops of cotton or corn will produce good crops of beans or hay. A clay or clay loam well supplied with humus is best adapted to this crop. Poor sandy soil will not produce a profitable yield.

Experiments at this Station seem to indicate that about 200 pounds of acid phosphate applied in the drill at planting time pays for its use. Lime either in the form of ground limestone, quick or air slacked, applied at the rate of two tons per acre once in three or four years, increases the growth of the soy bean plant, though it is not always necessary to the making of a good crop.

When the bean is planted for the first time, an application of three or four loads of stable or lot manure will materially increase the first crop. After the beans have been once grown successfully on a piece of land, the addition of nitrogenous fertilizer is not necessary to secure a profitable yield.

Soy bean land should be prepared in about the same manner as for cotton. The rows may be made from  $2\frac{1}{2}$  to  $3\frac{1}{2}$  feet wide. If the land is well drained, the rows may be laid off and the seed planted on a level surface; but if it is poorly drained, the seed should be on a low bed.

Soy beans may follow winter grain, if the stubble is plowed promptly and the beans planted immediately. In those sections where many hogs are raised and the fields fenced for pasturing, the corn rows may be made six feet wide, and a row of beans planted in each corn middle. The corn and beans are cultivated together. After pulling the corn, the beans may be grazed by hogs and cattle. If it is desired to make hay of them, they may be cut with a scythe or sharp hoe.

## INOCULATION

Soy beans require inoculation in order that they may take up nitrogen from the air. While natural inoculation is widely distributed, it is often advisable to employ artificial inoculation when the soy bean is grown for the first time.

The inoculation of the seed may be done either by scattering in the drill with the seed 200 or 300 pounds of inoculated soil per acre from some bean field,



or by the use of artificial cultures. Cultures may be obtained from commercial companies or in small amounts from the U. S. Department of Agriculture, Office of Soil Bacteriology, Washington, D. C.

Soy beans may be sown with a cotton or a corn planter, provided with proper plates, any time from April 15 to July 15. The seed should not be planted when the ground is very wet or very cold. They should be covered not more than two inches deep. As soon as the plants come up they should be cultivated shallow—usually about three times.

When soy beans are drilled for seed, the rate of seeding is about two pecks per acre. When they are sown broadcast for hay, the rate is about eight pecks; when planted as a mixture for hay, about four pecks of beans and four of cowpeas are necessary to secure a good stand and to get a good quality of hay.

#### HARVESTING AND THRASHING

The time to harvest soy beans is when most pods are ripe and half of the leaves fallen off. If left until the pods become fully ripe, the pods burst open and scatter the beans on the ground. If to be made into hay, it should be mowed when the pods are well formed.

When only a patch is planted, the soy bean plants may be cut with a sharp hoe, corn knife, scythe, or pulled up, and put in small piles to cure. When several acres are grown, they may be cut with a mower, self-rake, reaper, or binder and piled until they are cured. If the acreage is large, the harvesting of the seed may be done with a special bean harvester, several kinds of which are now on the market.

The soy bean can be thrashed with an ordinary grain separator, if the speed of the cylinder is reduced to about half of that for grain and some of the spikes from the concave are removed. When the amount to be thrashed is small, the dry plants may be spread out on the floor or wagon sheet, and the seed beaten out with a flail.

Soy beans heat quickly when stored in bulk, if not thoroughly dry. After thrashing they should be spread out to dry, or sacked and piled in such a way that they will be well ventilated.

#### VARIETIES

The Experiment Station has tested many different varieties or strains for seed production during the past

10 years. During this period the four most productive varieties of each year for seed included Mammoth Yellow six times; Blackbeauty five times; Hollybrook four times; and Edward, Haberlandt, Ebony and Wilson each three times.

In the last five-year period, Hollybrook averaged 15.1 bushels of seed per acre; Blackbeauty 13.9 bushels; Mammoth Yellow 13.3 bushels; and Ebony 12.4 bushels. The varieties which lead in seed production have rather coarse, erect stems, and are medium late. The early varieties never rank high in yield of either seed or forage.

The farmer will make no mistake in choosing the Mammoth Yellow for this latitude. It is a rank growing variety, has medium large yellow seed, and requires about 135 days to mature a crop of seed. It produces good hay. Hollybrook produces a smaller plant and has yellow seed. It requires about 125 days to make a crop of seed. Blackbeauty and Ebony are black seeded varieties.

For the production of hay, Mammoth Yellow, Hollybrook, Ebony and Biloxi are recommended. On good land they produce from one to two tons of hay that is of high feeding value, being similar in composition to hay from cowpeas, clover and alfalfa.

NOTE:—For a full discussion of varieties, fertilizers, culture, harvesting, and uses of soy beans, ask for Bulletin No. 203 of the Alabama Experiment Station.

BULLETIN No. 203

November, 1918

ALABAMA

# Agricultural Experiment Station

OF THE

Alabama Polytechnic Institute

AUBURN

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## Soy Beans in Alabama

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By

E. F. CAUTHEN

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1918

Post Publishing Company  
Opelika, Ala.

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Mammoth Yellow Soy Beans in the Variety Test for Hay

# SOY BEANS IN ALABAMA

BY E. F. CAUTHEN

## SUMMARY

The soy bean is a leguminous crop that is well adapted to many parts of Alabama.

In a fertilizer test on sandy land, for the production of hay, acid phosphate applied at the rate of 240 pounds per acre gave an average increase in yield of 504 pounds, and kainit applied at the same rate gave no increase. When 48 pounds of nitrate of soda was added to 240 pounds of acid phosphate and 240 pounds of kainit, neither the nitrate of soda nor kainit gave any increase in yield of hay.

In the production of grain neither acid phosphate, potash, nor nitrate of soda gave appreciable increases. On poor soil cotton seed meal gave sufficient increase to justify its use. Lime gave some increase.

In a comparison of acid phosphate and raw phosphate on seed production, the gain from the use of 320 pounds of acid phosphate per acre was .5 bushel, and from the use of 320 pounds of rock phosphate was 1.2 bushels. When similar amounts of acid phosphate and rock phosphate were used for hay production, the gain from the acid phosphate was 323 pounds of hay per acre and from the rock phosphate 243 pounds.

Experiments with disinfected seed planted on soil where soy beans had not been grown for many years and where beans had never been grown gave some inoculated plants. When disinfected seed were planted on land well supplied with barnyard manure, the plants bore many nodules the first year.

The largest yield of seed and straw came from drilling five pecks per acre. The yield of grain from three pecks was nearly as great as from five pecks. The plants of the Mammoth Yellow variety in thick seeded plots stood up better than those of the thin seeded plots.

Variety tests conducted for the past 11 years show that Blackbeauty stood at the head in seed production three years; Haberlandt two years; Mammoth Yellow, Sherwood, Tokyo, Hollybrook, and Biloxi one year each. During this 11 year period the four most pro-

ductive varieties of each year included Mammoth Yellow seven times; Blackbeauty and Hollybrook each five times; Edward, Haberlandt, Ebony, and Wilson each three times; Baird, Acme, Shanghai, and Swan each two times; Flat King, Peking, Sherwood, Virginia, Biloxi, and Ootootan each one time.

The varieties leading in production of seed have coarse, erect stems and require from 115 to 135 days to mature seed. The early varieties never ranked high in seed or hay production.

The percentage of straw to grain differs with different varieties. Blackbeauty averaged 42 per cent of grain; Hollybrook, 40 per cent; Ebony, 38 per cent; Mammoth Yellow, 34 per cent; Biloxi, 29 per cent; Ootootan, 26 per cent, and Barchet, only 18 per cent.

In 1917 in co-operation with the U. S. Department of Agriculture, 41 varieties and strains were grown,—28 of which yielded 50 per cent less grain than Mammoth Yellow, and none of which equalled it. The varieties differed widely in per cent of fat and protein—there being 10 per cent between the highest and lowest yielding varieties.

Soy beans make excellent hay and are easily cured. In a test of 10 varieties the average yield of hay ranged from 2332 pounds per acre to 5658 pounds. They required from 85 to 112 days from date of planting to date of mowing. The late varieties made the largest tonnage.

Mammoth Yellow and Biloxi are erect and make a somewhat woody hay. Some of the varieties like Ebony, Hollybrook, Wilson, and Ootootan have an abundance of leaves and produce a good quality of hay.

The rate of seeding for hay of the Mammoth Yellow variety giving the largest tonnage was 45 pounds per acre drilled in  $2\frac{1}{2}$  foot rows. The thicker seeding gave a better quality of hay, having less coarse, woody stems.

Soy beans and cowpeas mixed at the rate of five pecks each and seeded broadcast produced an average of about  $1\frac{1}{4}$  tons of excellent hay. The amount of hay was not greatly increased by combining the two legumes, though its quality and ease of curing were increased. When the rate of seeding was reduced from five pecks to 48 pounds per acre and sown broadcast, the yield was not reduced; but when the soy beans were seeded alone at the rate of 64 pounds per acre, the

yield of hay was about half that from the cowpeas when seeded alone.

The soy bean as a soil improving crop is shown by comparing the fertilizing effect of soy beans, cowpeas and corn on a following cotton crop. The average yield of seed cotton following corn was 1141 pounds; following cowpeas 1426 pounds; and following soy beans 1459 pounds. The increase due to the fertilizing effect of the cowpeas was 285 pounds seed cotton, and of the soy beans 318 pounds. If the value of the seed cotton is reckoned at 4 cents per pound, the fertilizing effect of the cowpeas would be \$11.40 per acre; and of the soy beans \$12.72.

The fertilizing effect of soy beans on a following hay crop is shown when a comparison is made of the yields of hay grown on corn lands, cowpea land and soy bean land. The average yields of hay made from a mixture of Red Rust Proof oats and Crimson Clover, from Blue Stem Wheat and Crimson Clover, and from Crimson Clover alone was 4249 pounds per acre when they followed soy beans; 4268 pounds per acre when they followed cowpeas; and only 3391 pounds after corn. The increase due to the fertilizing effect of soy beans was 858 pounds of hay, and of cowpeas 877 pounds. If the value of the hay is reckoned at \$15 a ton, the fertilizing effect of the soy beans over the corn was \$6.43 per acre, and of the cowpeas over the corn was \$6.56.

In a comparison the fertilizing effect of a crop of corn and of soy beans on a following winter oat crop the increased yield of the soy bean land over corn land was 173 per cent.

The comparative average yield of corn, cowpea and soy bean grain based on an eight year period was 1677 pounds of corn, 611 pounds of cowpeas, and 721 pounds of soy beans.

The most common enemies to the soy bean are rabbits, nematodes, wilt, and root-rot.

A brief description of leading varieties is given.



## SOY BEANS IN ALABAMA

## INTRODUCTION

The soy bean, sometimes called "soya" or "soja" bean, is becoming an important crop in Alabama. It has been grown mostly in small patches; but since many farmers have become acquainted with its merits, it is becoming a field crop, and its acreage is rapidly increasing.

The increasing interest in soy beans is due largely to a changed system of cotton farming made necessary by the invasion of the boll weevil, and to the discovery of many uses for the bean and its products. In looking for crops that can partly take the place of cotton, the farmer has found that the soy bean and the peanut fills the place to a considerable extent.

The livestock farmer and feeder desires crops that can to some extent take the place of corn and expensive mill feeds. The soy bean and its products are meeting those needs. The bean is being used also for human food.

These, with other uses, have caused the price of the bean to advance in the past three years over 100 per cent. It seems safe to predict that the price will continue to be profitable, and that the growing of soy beans in those sections where they are well adapted will eventually become a prominent part of Alabama's cropping system.

## CLIMATE AND SOIL REQUIREMENTS

The soy bean is adapted to the soil and climatic conditions of Alabama. Any land that will grow good crops of corn and cotton will produce good crops of soy beans, but poor soil will not produce a profitable yield. The best soil is a clay loam or clay, well supplied with humus.

Soy beans resist drought and excessive rain better than corn. On heavy land they make a better crop than either cowpeas or peanuts.

For the Coastal Plain section of the State the peanut is probably a better paying crop than the soy bean, but for the Black Belt, Piedmont and Tennessee Valley sections the soy bean is probably a more profitable crop. The Mammoth Yellow variety does well in all these sections where the soil is not too poor. In extremely fertile valleys the plants grow large and do not yield seed in proportion to size of plants.



## FERTILIZERS FOR SOY BEANS

In 1904 and 1906 fertilizer tests were made by Professor J. F. Duggar on sandy loam to determine the value of phosphoric acid, potash, and nitrogen on soy beans. The 1904 test followed an experiment in crimson clover which failed. The 1906 test (A) followed crimson clover cut for hay, and test (B) followed a crop of peanuts. The beans were planted about May 20, and mowed for hay about September 10.

TABLE I. *Fertilizer Test for Hay*

*Yield of Soy Bean Hay When the Following Fertilizer Was Used Per Acre.*

| YEARS               | 240 lbs. Acid<br>Phosphate | 240 lbs. Kainit | 240 lbs. Acid<br>Phosphate<br>240 lbs. Kainit | 240 lbs. Acid<br>Phosphate<br>240 lbs. Kainit<br>48 lbs. Nitrate<br>of Soda | No fertilizer |
|---------------------|----------------------------|-----------------|-----------------------------------------------|-----------------------------------------------------------------------------|---------------|
|                     | Lbs.                       | Lbs.            | Lbs.                                          | Lbs.                                                                        | Lbs.          |
| 1904 -----          | 2240                       | 1840            | 2320                                          | 2800                                                                        | 2560          |
| 1906 (A) ----       | 4232                       | 3296            | 4128                                          | 4528                                                                        | 4080          |
| 1906 (B) ----       | 5232                       | 4702            | 4752                                          | 4320                                                                        | 3552          |
| Average<br>increase | 504                        | —118            | 326                                           | 486                                                                         | ---           |

From the yield of hay in the three experiments recorded in Table I, acid phosphate gave an average increase of 504 pounds, and potash gave no increase. When the potash was combined with acid phosphate, no appreciable increase attributable to the kainit was secured. From the addition of 48 pounds of nitrate of soda to kainit and acid phosphate, no increase attributable to either potash or nitrate of soda was secured.

In the above experiments acid phosphate was the only fertilizer that paid for its use.

When the amount of acid phosphate in combination with the 240 pounds of kainit per acre was doubled, the increased yield of hay due to the phosphate was slightly more than double; but when the amount of kainit with 240 pounds of acid phosphate was doubled the increased yield due to potash was negligible.

## FERTILIZER TEST FOR SEED AND HAY

The experiments recorded in Table II show in a general way the effects of fertilizing elements on soy

beans. The test of 1917 was made on a poor, deep, sandy soil, the fertility of which gradually increased from one side of the experiment to the other, as is shown by the gradual increase in yield of the check plots. The 1918 test was on a fertile, loamy soil and followed a heavy crop of crimson clover plowed under in March for soil improvement. The fertilizer, except lime, was applied in the drill at planting time and mixed with the soil. The lime was scattered broadcast over the plot and harrowed in the surface.

TABLE II.—*The Yield of Soy Bean Seed, Straw and Hay from the Use of Different Kinds of Fertilizers*

| Plot No. | FERTILIZER                |                      | 1917                            |                                  | 1918                            |                                  |                                |
|----------|---------------------------|----------------------|---------------------------------|----------------------------------|---------------------------------|----------------------------------|--------------------------------|
|          | Am't. fertilizer per acre | KIND OF FERTILIZER   | Yield of soy bean seed per acre | Yield of soy bean straw per acre | Yield of soy bean seed per acre | Yield of soy bean straw per acre | Yield of soy bean hay per acre |
|          |                           |                      |                                 |                                  |                                 |                                  |                                |
|          | Lbs.                      |                      | Bu.                             | Lbs.                             | Bu.                             | Lbs.                             | Lbs.                           |
| 1        | 00                        | No fertilizer -----  | 6.7                             | 787                              | 20.8                            | 2424                             | 5112                           |
| 2        | 240                       | Acid phosphate ----  | 6.9                             | 763                              | 21.6                            | 2664                             | 5088                           |
| 3        | 200                       | Kainit -----         | 10.0                            | 1017                             | 17.2                            | 2736                             | 4440                           |
| 4        | 200                       | Cotton seed meal -   | 13.9                            | 1411                             | 20.4                            | 2208                             | 4224                           |
| 5        | 100                       | Nitrate of soda ---- | 9.4                             | 960                              | 21.5                            | 2520                             | 4944                           |
| 6        | 2000                      | Slacked lime -----   | 11.7                            | 1286                             | 25.6                            | 2688                             | 4752                           |
| 7        | 00                        | No fertilizer -----  | 11.7                            | 1228                             | 23.6                            | 2724                             | 4800                           |
| 8        | 240                       | Acid phosphate -     | 9.6                             | 1152                             | 23.2                            | 2688                             | 4848                           |
|          | 200                       | Kainit -----         |                                 |                                  |                                 |                                  |                                |
| 9        | 240                       | Acid phosphate -     | 15.2                            | 1488                             | 19.2                            | 2736                             | 4320                           |
|          | 200                       | Cotton seed meal -   |                                 |                                  |                                 |                                  |                                |
| 10       | 200                       | Kainit -----         | 17.3                            | 1555                             | 20.4                            | 2232                             | 3984                           |
|          | 200                       | Cotton seed meal -   |                                 |                                  |                                 |                                  |                                |
| 11       | 2000                      | Fine ground lime -   |                                 |                                  |                                 |                                  |                                |
|          |                           | stone -----          | 21.5                            | 1853                             | 18.8                            | 2484                             | 4512                           |
| 12       | 240                       | Basic slag -----     | 19.7                            | 2203                             | 21.2                            | 2400                             | 4680                           |
| 13       | 00                        | No fertilizer -----  | 19.7                            | 1929                             | 18.6                            | 2208                             | 4800                           |

Lime gave a small increase in grain; of the two forms of lime, (slacked and fine ground limestone) the former gave the better results. Acid phosphate, kainit and nitrate of soda gave no appreciable increase. On poor soil cottonseed meal increased the yield of grain sufficient to more than pay for its cost.

The large yield of grain, straw and hay in the 1918 test was due largely to the favorable seasons and the heavy cover crop of crimson clover plowed under in the spring for soil improvement.

## ACID PHOSPHATE VERSUS RAW PHOSPHATE

In Table III is found a comparison of the effect of acid phosphate and raw phosphate (finely ground untreated phosphate rock) on the production of soy bean seed. The experiment was conducted on a strong red soil. The plots received the same amount of fertilizer in the fall when they were planted in oats. When the oats were harvested in the spring, the land was plowed and fertilized again at the rate indicated in the table, and planted in soy beans. The low yield of beans is largely due to the late planting.

TABLE III.—*The Yield of Soy Bean Seed Per Acre from the Use of Acid Phosphate and Raw Phosphate*

| Rate per<br>acre                | 1909 | 1910 | 1914 | 1915 | 1916 | 1917 | 1918 | Average<br>yield | Average<br>increase |
|---------------------------------|------|------|------|------|------|------|------|------------------|---------------------|
|                                 | Bu.  | Bu.  | Bu.  | Bu.  | Bu.  | Bu.  | Bu.  | Bu.              | Bu.                 |
| Acid Phosphate<br>320 lbs. .... | 5.5  | 8.5  | 4.5  | 10.7 | 6.7  | 9.6  | 7.4  | 7.6              | .8                  |
| Raw Phosphate<br>320 lbs. ....  | 7.2  | 8.3  | 4.8  | 11.3 | 7.9  | 9.9  | 8.5  | 8.3              | 1.7                 |
| No Phosphate ..                 | 5.3  | 7.0  | 4.9  | 9.7  | 5.9  | 9.1  | 5.9  | 6.8              | --                  |

From the application of 320 pounds of acid phosphate per acre, the average gain was only .8 bushels, and from the same amount of rock phosphate the average gain was 1.7 bushels.

TABLE IV.—*The Yield of Soy Bean Hay Per Acre from the Use of Acid Phosphate and Raw Phosphate*

| Rate per<br>acre           | 1904 | 1908 | 1912 | Average<br>yield | Average<br>increase |
|----------------------------|------|------|------|------------------|---------------------|
|                            | Lbs. | Lbs. | Lbs. | Lbs.             | Lbs.                |
| Acid Phosphate 320 lbs. .. | 2832 | 2256 | 1676 | 2255             | 323                 |
| Raw Phosphate 320 lbs. ..  | 2720 | 2192 | 1613 | 2175             | 243                 |
| No Phosphate .....         | 2800 | 1648 | 1348 | 1932             | ---                 |

The yield of hay as a result of fertilizing with acid phosphate and rock phosphate is shown in Table IV. This experiment was conducted on the same land and followed the same plan as that reported in Table III.

The average increase from the use of 320 pounds of acid phosphate per acre was 323 pounds of hay and

from a similar amount of raw phosphate 243 pounds. In this experiment the acid phosphate proved slightly better fertilizer than rock phosphate. Neither fertilizer, however, gave a marked increase in yield.

#### INOCULATION

The soy bean like other legumes has the ability to utilize atmospheric nitrogen through the action of bacteria which live on its roots. These bacteria develop tubercles on the roots of the plants. If there are no tubercles present and the plants are pale green, it is an indication that inoculation is lacking or deficient.

#### INOCULATION EXPERIMENTS

In 1902 inoculation experiments were made in pots by use of soil from fields where soy beans had not been grown. With seed disinfected in 2 per cent solution of formalin, certain pots were planted June 18 without inoculation, and on August 12, 64 per cent of the plants had tubercles. About the same per cent of inoculation was secured from disinfected seed planted in cowpea and peanut soil. With disinfected seed planted in soil fertilized with cow manure, 100 per cent of the plants showed inoculation.

In 1903 similar experiments were made, using soil on which no legumes had been grown for six years. The plants bore many nodules. In one set of pots the soil was limed; in another set it was not limed. In those pots limed the plants bore more tubercles than those planted in unlimed pots.

In later years both disinfected and inoculated seed was planted on land where no soy beans had ever grown. Wherever tubercles were found, they were found on plants from both disinfected and inoculated seed alike.

Land that has been well fertilized with barnyard manure or is naturally fertile and planted with seed harvested in the ordinary manner will probably need



Well Inoculated Plant



no artificial inoculation, as there may be sufficient bacteria on the seed to inoculate the growing plants. If the land lacks humus or is poor, artificial inoculation may prove beneficial and should be done either before or at planting time.

Inoculation of seed may be done either by scattering in the drill with the seed inoculated soil from a soy bean field, or by the use of bacterial cultures. Soy bean cultures may be obtained from commercial companies or from the U. S. Department of Agriculture, Office of Soil Bacteriology, Washington, D. C. The latter will furnish any farmer enough to inoculate two acres. Instructions how to use the cultures usually accompany each package.

#### CROPPING SYSTEMS

The growing of soy beans fits well into many of the cropping systems employed in the Cotton Belt. As a grain crop they may occupy some of the land formerly planted in cotton or corn. When winter oats and wheat are harvested in time to allow the stubble to be plowed, it may be planted in beans, either for seed, hay, or grazing.



A Row of Soy Beans Growing in a Six Foot Corn Middle. The Beans are Easily Cultivated and Do Not Seem to Reduce the Yield of Corn.



In the sections where many hogs are raised and the fields fenced for pasturing, the corn rows may be made six feet wide and a row of beans planted in the middle thus forming alternate rows of corn and beans. Both crops may be "hogged off." Where the bean harvester is employed, it will harvest the soy beans without damage to the standing corn.

#### PREPARATION OF LAND FOR SOY BEANS

The land for soy beans may be prepared as for cotton. It should be plowed in the early spring and harrowed once or twice before planting to destroy weeds and clods and to make a good seed bed. Where the land is smooth and well drained, the rows can be laid off and the beans planted on a level.

Stubble land should be plowed as soon as the grain is removed and the seed planted in moist soil either on a low bed or in drill slightly below the surface.

#### PLANTING SOY BEANS

Soy beans may be planted any time from April 15 to July 15. Prompt germination is important, and to secure it, the seed should not be planted when the soil is very cold, wet or dry. Conditions favorable to germination and growth of cowpeas are suitable for soy beans.

When grown for seed purposes, they should be planted in rows from 30 to 36 inches wide. The seed may be planted by hand or by the use of a grain drill or planter equipped with proper plates. The seed should be covered not more than 2 or 3 inches deep.

#### RATE OF SEEDING

Table V. gives the rate of seeding the Mammoth Yellow variety for grain. The 1917 test was planted on gravelly loam soil. The stand of plants in both tests was almost perfect. In the latter test the beans were over-ripe when they were harvested and sustained an estimated loss of 5 per cent from **shattering**.

TABLE V.—*Rate of Seeding Mammoth Yellow Soy Beans for Grain*

| Amount of seed planted per acre | 1917                    |                         | 1918                    |                         | Averages                |                         |
|---------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
|                                 | Yield of grain per acre | Yield of straw per acre | Yield of grain per acre | Yield of straw per acre | Yield of grain per acre | Yield of straw per acre |
|                                 | Bu.                     | Lbs.                    | Bu.                     | Lbs.                    | Bu.                     | Lbs.                    |
| 1 peck -----                    | 14.6                    | 2684                    | 7.5                     | 2924                    | 11.1                    | 2804                    |
| 2 pecks -----                   | 15.5                    | 2926                    | 8.6                     | 2809                    | 12.1                    | 2867                    |
| 3 pecks -----                   | 18.7                    | 3520                    | 9.1                     | 2784                    | 13.9                    | 3152                    |
| 4 pecks -----                   | 16.7                    | 3432                    | 10.2                    | 2425                    | 13.5                    | 2928                    |
| 5 pecks -----                   | 17.2                    | 3630                    | 10.9                    | 2803                    | 14.1                    | 3216                    |

The maximum average yield of grain and of straw came from seeding five pecks per acre. It is noticed that the yield of grain from three pecks was greater than from four pecks and nearly as much as from five pecks per acre. The usual rate when drilled and cultivated for grain is from two to three pecks per acre.

The plants of the thick seeded plots stood up better, than those of the thin seeded plots. This is an important consideration if the seed is harvested with machinery.

When soy beans alone are sown broadcast for hay, the usual rate of seeding is from one to two bushels per acre; when they are sown in combination with cowpeas the usual rate is one bushel of peas and one of beans. From the experiments that are recorded on page 111 the yield of hay can be increased, and its quality greatly improved by increasing the above rate of seeding.

#### TILLAGE

The same implements used for cultivation of cotton can be used for cultivating soy beans. If the rows are uniform in width, a "Gee Whiz" cultivator may be used to make one trip to the middle while the plants are small; later cultivations can be made with scooter and scrape. The crop should receive frequent shallow cultivation till the plants begin to bloom.

#### HARVESTING SOY BEANS

The time to cut for seed is when most pods are ripe and some leaves have fallen, just before the pods begin to burst and scatter the beans on the ground. If the pods are left on the plants to get completely ripe, the

seed shatter badly when harvested with binder or mower; but if the seed is to be harvested with a special soy bean harvester, the plants should stand until the pods become thoroughly ripe.

When only a patch is planted, the plants can be cut with a corn knife or sharp hoe, or pulled up, and cured in small piles and thrashed out with a flail. Where several acres are grown, they may be cut with a mower, self rake reaper, or binder, and raked or dumped into small piles to cure. As soon as they are cured, they should be put under a shed or thrashed.

The special bean harvester, of which there are several kinds now in use, has revolving arms working in a large box, which is mounted on wheels and drawn by two horses. While the machine is passing over a row, the revolving arms strike the plants and knock out the ripe beans, which are caught in the box. A team and two men harvest about five or six acres a day. The harvester is not started in the morning until after the dew dries off. When such a machine is used, probably 20 per cent of the crop is shattered on the ground, or is left on the plants. When such is the case, hogs should be permitted to run in the fields and gather them.

#### THRASHING AND STORING SEED

Where the acreage is small, the plants may be spread on a floor or wagon sheet to dry, after which they can be beaten out with a flail.

Soy beans can be thrashed with an ordinary grain thrasher, if the speed of the cylinder is reduced to about half of that for grain (about 300 revolutions per minute) and some of the spikes removed from the concave. The slowing down of the cylinder may be secured by building up the diameter of the drive pulley. If the speed is not reduced, many seed will be lost. The other parts of the separator must run at the normal speed, otherwise straw and chaff will clog the shaker and beater, and poor separation will result.

If the thrashed beans are stored damp or in a damp place, they will heat and become unfit for planting. By putting them in bags and piling the bags in such a way that good ventilation is secured, they may be kept without much injury for one or two years. However, long storing reduces their percentage of germination and a germination test of old seed should be made before planting them.

## VARIETY TESTS FOR SEED

Up to the present time the Experiment Station has tested 30 different varieties or strains for seed production. Much larger numbers have been grown for observation purposes. Most of the varieties have been furnished by the U. S. Department of Agriculture. Many of them did not offer any great promise for this locality and were dropped after being tested one or two years.

In the table below is given the results of the variety test for 11 years. Some varieties only one year; others like Mammoth Yellow and Ebony, which were more promising, were included almost every year. No column of average yield is made, because many varieties were not planted every year, and obviously it would be unfair to average and compare varieties grown in different years. However, a variety may be compared with any other variety grown in the same year.

In the variety tests the beans were usually planted on one-thirty second acre plots, in rows three feet wide, sowed by hand and thinned to a uniform stand of three or four plants per foot. Each plot received frequent shallow cultivation until the pods began to appear.

A study of the table shows that no one variety has stood at the head of the list for all years. Variations in soils and seasons from year to year produce fluctuations in yield of a variety. During the 11 year period Blackbeauty stood at the head three years in production of seed; Haberlandt, two years; Mammoth Yellow, Sherwood, Tokyo, Hollybrook and Biloxi one year each. During the 11 year period the four most productive varieties for seed of each year included Mammoth Yellow seven times; Blackbeauty five times; Hollybrook five times; Edward, Haberlandt, Ebony and Wilson each three times; Baird, Acme, Shanghai, and Swan each two times; Flat King, Peking, Sherwood, Virginia, Biloxi and Otfootan each one time.

TABLE VI.—Yields of Grain of Different Varieties

| Varieties            | Yield of seed per acre (bushels) |      |      |      |      |      |      |      |      |      |       |      | Lbs. of straw per acre |
|----------------------|----------------------------------|------|------|------|------|------|------|------|------|------|-------|------|------------------------|
|                      | 1908                             | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1918  | 1917 | 1918                   |
| Acme 14954           | ---                              | ---  | 12.5 | ---  | ---  | ---  | ---  | ---  | 8.0  | ---  | ---   | ---  | ---                    |
| Arlington 22899      | ---                              | ---  | ---  | ---  | ---  | ---  | 5.2  | 12.0 | 8.0  | ---  | ---   | ---  | ---                    |
| Austin 17263         | ---                              | ---  | ---  | ---  | ---  | ---  | 2.4  | 3.2  | 6.6  | 10.9 | 12.7  | 1680 | 1160                   |
| Biloxi 125           | ---                              | 5.1  | 8.8  | 11.2 | 8.6  | ---  | ---  | ---  | ---  | ---  | ---   | ---  | ---                    |
| Baird 22333          | ---                              | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 15.0 | 22.5  | 2520 | 2700                   |
| Barchet 23232        | ---                              | 9.8  | 9.6  | 14.6 | 11.3 | 9.7  | ---  | ---  | ---  | ---  | ---   | ---  | ---                    |
| Blackbeauty          | ---                              | 4.6  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---   | ---  | ---                    |
| Ebony 17254          | ---                              | ---  | 9.6  | 14.3 | 15.3 | 23.5 | 11.6 | 16.0 | 4.4  | 9.0  | 10.8  | 3060 | 2300                   |
| Edward 14953         | 5.4                              | 9.6  | 8.9  | 12.4 | 14.2 | 19.4 | 5.2  | 10.3 | 11.6 | 14.0 | 16.0  | 1320 | 1160                   |
| Flat King 17252      | ---                              | 11.2 | 8.5  | ---  | 10.6 | 15.5 | 5.2  | 9.4  | 16.2 | 15.3 | 16.3  | 1722 | 1425                   |
| Hollybrook 17278     | ---                              | 9.1  | 9.0  | ---  | 17.3 | ---  | ---  | ---  | ---  | ---  | ---   | ---  | ---                    |
| Haberlandt           | ---                              | ---  | 11.3 | 10.2 | 13.3 | 21.5 | 4.8  | 10.3 | 12.9 | 26.0 | 20.8  | 2400 | 1850                   |
| Ito San 186          | ---                              | ---  | 12.6 | 16.6 | 18.3 | 12.3 | ---  | ---  | ---  | ---  | ---   | ---  | ---                    |
| Mammoth Yellow       | ---                              | ---  | 3.2  | ---  | ---  | ---  | ---  | ---  | ---  | 9.9  | ---   | 1422 | ---                    |
| Medium Green 92      | 9.1                              | 9.2  | 10.6 | ---  | 17.8 | 17.0 | 5.4  | 13.4 | 11.5 | 19.3 | 18.0  | 2283 | 2162                   |
| Medium Yellow        | ---                              | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 7.0  | ---  | ---   | ---  | ---                    |
| Morse 19186          | ---                              | ---  | ---  | ---  | ---  | ---  | 4.0  | ---  | 5.6  | 7.2  | ---   | 1728 | ---                    |
| Otootan              | ---                              | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 7.5  | ---  | ---   | ---  | ---                    |
| Peking 17852         | ---                              | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 15.0 | 21.3  | 3600 | 3875                   |
| Peking 152           | ---                              | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---   | ---  | ---                    |
| Rueland 20797        | ---                              | ---  | ---  | ---  | ---  | ---  | 5.6  | 8.9  | ---  | 9.8  | 7.4   | 1452 | 1480                   |
| Shanghai 14952       | 6.2                              | 4.8  | 8.9  | ---  | 15.0 | ---  | ---  | ---  | ---  | ---  | ---   | ---  | ---                    |
| Sherwood 17862       | ---                              | 15.4 | 9.7  | ---  | 15.3 | ---  | ---  | ---  | ---  | ---  | ---   | ---  | ---                    |
| Swan 22379           | ---                              | 3.6  | 7.1  | 12.4 | 12.9 | 17.8 | ---  | ---  | ---  | ---  | ---   | ---  | ---                    |
| Tar Heel             | ---                              | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---   | ---  | ---                    |
| Tokyo 17267          | ---                              | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 4.5  | ---  | ---   | ---  | ---                    |
| Wilson (black) 19183 | 5.4                              | 11.0 | 13.0 | ---  | 12.2 | ---  | ---  | ---  | ---  | ---  | ---   | ---  | ---                    |
| Wilson (yellow)      | ---                              | ---  | ---  | ---  | ---  | ---  | 5.6  | 11.7 | 5.4  | 10.0 | 12.0  | 1320 | 1280                   |
| Virginia 32906       | ---                              | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 24.0 | 24.0 | 27.60 | ---  | ---                    |
| Chinese 20797        | ---                              | 4.8  | ---  | ---  | ---  | 8.0  | ---  | ---  | ---  | 15.5 | 14.6  | 1806 | 1275                   |



The list of productive varieties is rather long, and the matter of making a choice of a variety by the beginner may be confusing.

He will make no mistake in choosing for this latitude the Mammoth Yellow, which is a rank growing variety and produces yellow seed. It requires about 135 days to mature a crop of seed. Hollybrook produces a smaller plant, has smaller yellow seed, and requires about 10 days less than Mammoth Yellow to mature its seed. Blackbeauty is very much like Hollybrook, except in color of seed, which is black.

The varieties which lead in seed production have rather coarse, erect stems and are medium late. The early varieties never rank high in seed production; nor are they well suited for hay. When it is desired to get an early crop for grazing purposes, Ito San, Swan, Sherwood and other early varieties described in Table VII. may be planted. They will bridge over the period till the later varieties like Mammoth Yellow, Hollybrook and Blackbeauty, etc., are ready for grazing.

#### SOY BEAN STRAW

The percentage of straw to grain differs with different varieties. In 1917 and 1918 Mammoth Yellow averaged 66 per cent of straw, and Ootootan averaged 74 per cent. The dwarf varieties have a lower percentage of straw than those that have a tendency to form a semi-vine upwright growth. Blackbeauty averaged for two years 42 per cent of grain; Hollybrook, 40 per cent; Ebony, 38 per cent; Biloxi, 29.5 per cent; and Barchet (an upright vine-like variety) only 18 per cent.

The amount of straw from each variety is not in proportion to yield of grain. The percentage of straw depends upon the habit of growth of the variety—the late vine-like varieties yielding the highest percentages and the largest amounts per acre.

In 1917 and 1918 the variety tests were planted on fertile sandy soil and made a rank growth. The Arlington No. 22899 made 1420 pounds of straw per acre, and Ootootan 3737 pounds, and Mammoth Yellow 2222 pounds.

Chemical composition and feeding experiments of soy bean straw show that it is a good roughage. The hulls and small stems are readily eaten by cattle and sheep. Lambs fed a ration of soy bean straw, shelled corn, and linseed meal made a fair gain.\*

\* Ohio Bulletin No. 245.

TABLE VII.—*Variety Characters of Beans*

| Varieties        | Color of blooms  | Average number of days from planting to |          | Color of seed   |
|------------------|------------------|-----------------------------------------|----------|-----------------|
|                  |                  | Blooming                                | Ripening |                 |
| Acme -----       | Purple -----     | 65                                      | 111      | Yellow          |
| Austin -----     | White -----      | 59                                      | 118      | Yellow          |
| Biloxi -----     | White and Purple | 100                                     | 150      | Brown           |
| Baird -----      | Purple -----     | 70                                      | 105      | Brown           |
| Barchet -----    | Pinkish -----    | 102                                     | 144      | Dark brown      |
| Blackbeauty ---- | Pink and Purple  | 55                                      | 110      | Black           |
| Chinese -----    | Pink -----       | 90                                      | 155      | Dark brown      |
| Ebony -----      | White and Purple | 72                                      | 117      | Black           |
| Edward -----     | Pink -----       | 67                                      | 130      | Greenish        |
| Hollybrook ----- | Purple -----     | 70                                      | 115      | Yellow          |
| Haberlandt ----- | Purple -----     | 80                                      | 130      | Yellow          |
| Ito San -----    | Purple -----     | 49                                      | 82       | Yellow          |
| Mammoth Yellow   | White and Purple | 68                                      | 133      | Yellow          |
| Morse -----      | -----            | 90                                      | 118      | Olive           |
| Otootan -----    | Pink -----       | 103                                     | 151      | Brown           |
| Peking -----     | Pink -----       | 80                                      | 120      | Black           |
| Shanghai -----   | White -----      | 65                                      | 119      | Black or red'sh |
| Swan -----       | White -----      | 55                                      | 110      | Yellow          |
| Tokyo -----      | Purple -----     | 65                                      | 118      | Green           |
| Wilson -----     | Purple -----     | 87                                      | 120      | Black           |
| Sherwood -----   | -----            | 57                                      | 103      | Yellow          |

## VARIETY TEST OF SOY BEANS FOR GRAIN AND OIL

In 1917 in co-operation with the Bureau of Plant Industry, U. S. Department of Agriculture, the Experiment Station grew 11 varieties and strains of soy beans. The seed came originally from different sources, and they were grown for the purpose of getting data on habit of growth, adaptability, yield of grain, chemical composition, etc. They were planted May 15 on sandy soil in rows 3½ feet wide and thinned to a uniform stand. The plots were small and planted in duplicate. Below is a table showing the results of one year's test:

TABLE VIII. *Yields of Seed and Straw, Date of Ripening, and Chemical Analyses of Varieties and Strains of Soy Beans Grown in Co-operation With U. S. Department of Agriculture*

| Bureau of Plant Industry Number | Date of ripening | Yield per acre   |                 | Chemical analyses* |              |         |
|---------------------------------|------------------|------------------|-----------------|--------------------|--------------|---------|
|                                 |                  | Bushels of grain | Pounds of straw | Water per cent     | Fat per cent | Protein |
| 30598-A                         | 9-10             | 8.8              | 1716            | 5.36               | 20.69        | 38.75   |
| 30746-A                         | 8-15             | 10.2             | 1420            | 5.20               | 23.02        | 33.40   |
| 35622                           | 9- 7             | 9.7              | 2323            | 6.34               | 24.30        | 29.90   |
| 35125                           | 9- 7             | 10.5             | 1214            | 6.19               | 22.22        | 33.00   |
| 36576                           |                  | 14.3             | 1069            | 7.29               | 23.38        | 32.60   |
| 36651                           | 8-15             | 11.0             | 607             | 7.36               | 23.37        | 30.50   |
| 36829                           | 9- 7             | 7.9              | 1610            | 6.21               | 24.18        | 32.60   |
| 36830                           | 9-10             | 14.1             | 2059            | 6.70               | 23.33        | 35.25   |
| 36846                           | 8-15             | 11.7             | 673             | 6.28               | 24.59        | 31.05   |
| 36901                           | 8-17             | 10.8             | 607             | 6.33               | 23.42        | 32.05   |
| 36847                           | 8-20             | 10.3             | 633             | 6.65               | 21.03        | 32.40   |
| 36903                           | 8-15             | 11.9             | 594             | 6.11               | 23.14        | 32.60   |
| 36904                           | 8-13             | 10.1             | 766             | 7.61               | 21.74        | 34.05   |
| 36905                           | 8-15             | 8.8              | 396             | 7.00               | 23.96        | 33.20   |
| 36915                           | 8-12             | 9.7              | 475             | 7.40               | 22.85        | 33.10   |
| 37042                           | 9-10             | 9.2              | 1567            | 5.80               | 23.64        | 33.55   |
| 37047                           | 9-19             | 14.8             |                 | 6.27               | 19.85        | 40.25   |
| 37062                           | 8-12             | 9.9              | 449             | 7.53               | 23.45        | 32.70   |
| 37077                           | 9- 7             | 5.3              | 1531            | 7.73               | 22.32        | 33.10   |
| 37230                           | 8-15             | 11.0             | 819             | 6.50               | 23.81        | 34.05   |
| 37232                           | 8-15             | 6.4              | 307             | 7.00               | 22.54        | 34.95   |
| 37239                           | 9-19             | 7.5              | 1399            | 7.01               | 23.37        | 32.80   |
| 37244                           | 9-24             | 12.8             | 1610            | 6.18               | 19.92        | 35.00   |
| 37245                           | 9-10             | 5.7              | 1505            | 6.66               | 21.88        | 32.60   |
| 37246                           | 9-17             | 11.0             | 1716            | 5.50               | 23.36        | 35.11   |
| 37250                           | 9-17             | 17.2             | 2138            | 6.34               | 21.70        | 38.05   |
| 37262                           | 9-24             | 11.9             | 2191            | 6.42               | 19.20        | 39.80   |
| 37272                           | 9-17             | 11.4             | 1426            | 5.55               | 22.59        | 37.10   |
| 37298                           | 9-15             | 15.8             | 1954            | 6.36               | 20.38        | 38.20   |
| 37335                           | 9-15             | 16.1             | 1690            | 6.79               | 21.76        | 38.10   |
| 37344                           | 9-19             | 18.8             | 1584            | 7.61               | 19.70        | 37.40   |
| 37570                           | 8-12             | 10.8             | 620             | 6.17               | 22.69        | 36.10   |
| 37571                           | 8-16             | 9.9              | 515             | 6.03               | 23.58        | 32.10   |
| 38218                           | 9-17             | 8.8              | 1768            | 6.28               | 21.54        | 39.00   |
| 38451                           | 9-19             | 18.9             | 2560            | 6.52               | 19.94        | 37.90   |
| 38455                           | 9-17             | 10.6             | 1478            | 6.15               | 20.36        | 38.40   |
| 38462                           | 9-19             | 19.4             | 2930            | 6.43               | 15.32        | 37.85   |
| 40114                           | 9-20             | 6.8              | 1448            | 6.25               | 21.19        | 33.75   |
| 40115                           | 9-20             | 9.7              | 1531            | 6.27               | 21.33        | 35.55   |
| 37301                           | 9-19             | 11.4             | 1954            | 6.70               | 21.63        | 34.45   |
| Mammoth                         | 9-22             | 23.3             | 2297            | 6.10               | 23.60        | 35.05   |

\*Reported by Bureau of Plant Industry, U. S. Department of Agriculture.



Dwarf and Cluster Habits of Some Varieties

The early varieties are dwarf in habit of growth, woody, and hard to harvest. The percentage of straw to beans is, in some dwarf varieties, less than 50; in the larger varieties it ranges from 60 to 75 per cent. The straw of dwarf varieties is not eaten closely by stock on account of its hard, woody nature.

The yield of seed from 28 strains and varieties fell 50 per cent below that of Mammoth Yellow; only four strains came within 25 per cent of Mammoth Yellow; none equalled it. From the standpoint of yield of seed and straw or hay, only four or five varieties offer any promise. They are being tested further.

In per cent of fat, many of the low yielding varieties and strains compare favorably with Mammoth Yellow. Fourteen varieties contain more protein than Mammoth Yellow. The protein content ranges from 29.9 in No. 35622 to 40.25 per cent in 37047.

#### SOY BEANS FOR HAY

The soy bean makes an excellent hay when harvested at the proper time. Its feeding value seems to be equal to that of alfalfa and cowpea hay. The average of 23 analyses shows that it contains 16 per cent crude protein, 21.9 per cent fiber, 39.1 per cent nitrogen-free extract, and 2.8 per cent fat.\* When used for this purpose, it should be cut after the pods begin to form, and before they are fully grown. If the cutting is

\*See page 640 "Feeds and Feeding," Henry and Morrison.



done too late, the stems become woody and the leaves shatter badly.

Soy beans can be mowed and cured in the same way as cowpeas. The plants should lie in the swath about two days, and then raked into windrows or thrown into small racks or on curing frames. If left in the swath or exposed to direct sunshine too long, the leaves dry and fall off badly, and the quality of the hay greatly deteriorates. After remaining in cocks, or windrows or on racks four or five days, the hay is cured, and should be promptly stored.

Some of the varieties are better suited for hay production than others. Those that have large, coarse, woody stems and short branches make a hay that is not closely eaten by stock. Nearly all the early varieties tested have a dwarf habit of growth, and therefore, do not lend themselves to hay production. Those varieties that require 125 days or more to mature seed give the largest yields of hay; those that have a vine or semi-vine habit of growth make the best quality of hay.

#### VARIETY TESTS FOR HAY

Table IX. shows the relative yield of hay of 10 leading varieties. They were planted in three foot rows at the rate of one bushel per acre, fertilized, and cultivated as a variety test.



Curing Soy Bean Hay on Racks



TABLE X.—*Yield of Hay of Varieties in 1917 and 1918*

| Varieties      | Year | Mammoth<br>Yellow | Wilson | Arlington | Barchet | Hollybrook | Ebony | Blackbeauty | Otootan | Biloxi | Virginia |
|----------------|------|-------------------|--------|-----------|---------|------------|-------|-------------|---------|--------|----------|
| Yield per acre | 1917 | 3660              | 2460   | 2580      | 2100    | 3500       | 3300  | 2700        | 5560    | 4140   | 2220     |
|                | 1918 | 2392              | -----  | 3380      | 2912    | 3276       | 3536  | -----       | 5756    | 4940   | 2444     |
| Average yield  | ---  | 3026              | ----   | 2980      | 2506    | 3388       | 3418  | ----        | 5658    | 4540   | 2332     |

In the above table the average yield of hay ranges from 2332 pounds per acre to 5658 pounds. At \$25.00 per ton the money value from the lowest yielding variety, Wilson, is \$29.15 per acre; for the highest yielding variety, Otootan, it is \$70.73 per acre.

Named in order in which they reached haymaking stage are Wilson, Virginia, Ebony, Hollybrook, Blackbeauty, Arlington, Barchet, Mammoth Yellow, Biloxi and Otootan. They required from 85 to 112 days from date of planting to date of mowing for hay.

Mammoth Yellow and Biloxi grow erect and are coarse; Ebony, Blackbeauty, and Hollybrook have slender stems and many branches; the other varieties grow three or four feet in height with an abundance of leaves and branches, and, although they are erect in manner of growth, the ends of the branches have a considerable tendency to twine or form long, slender, weak vine-like stems.

In 1918 wheat stubble land was plowed and planted June 20th in Mammoth Yellow soy beans. The rows were 30 inches wide and seed dropped in drill. At time of planting a mixture of 160 pounds of acid phosphate and 60 pounds of cotton seed meal was applied in the drill. The beans were given two cultivations. They were cut September 17th and cured on racks.

TABLE XI. *Rate of Seeding and Yield of Hay Per Acre*

| Seed per<br>acre | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
|------------------|------|------|------|------|------|------|------|------|
|                  | 15   | 60   | 80   | 100  | 120  | 140  | 160  | 180  |
| Yield of hay     | 3680 | 3200 | 2752 | 2848 | 2400 | 2096 | 1888 | 1936 |

In the table it is noticed that the yield of hay gradually decreased as the rate of seeding increased. The large yield of hay from the small rate of seeding is explained by the unfavorable weather conditions of August, which was dry. The thickly seeded plants did not make a large growth, but they made a very fine quality of hay being free from coarse, woody stems.

The 30 inch width of row commends itself because its middle is easy to cultivate with one furrow of a harrow or scrape and two rows can be mowed at one trip with a five foot blade. The mowing is made easy, if the rows are uniform in width and laid by level; the curing may be hastened by removing dividing board from mower and allowing the beans to fall over the whole swath.

#### MIXTURE OF COWPEAS AND SOY BEANS FOR HAY

Cowpeas and soy beans when seeded together form a mixture that produces an excellent quality of hay. The advantages of a mixture over either crop alone are that the combined yield is, in many cases, increased; that the curing of the cowpeas is made easier because of the stemmy nature of the soy bean, and that, as a result of the better curing, the quality of the hay is improved. However, either crop alone makes excellent hay when harvested at the right stage and properly cured.

To secure an increase in yield when soy beans are seeded with cowpeas, they must not be planted on too poor land or suffer from an unfavorable season. When the conditions are not favorable to prompt growth, weeds and grass choke the beans and their growth is not proportionate to the cowpeas.

The time from planting to proper haymaking stage is about 70 or 80 days. The mixture is harvested and made into hay in the same way that cowpea hay is made. The stems of the beans hold the cowpea vines apart, and the mixed hay cures more rapidly than cowpea hay alone. Care should be exercised in handling the hay to prevent the loss of leaves, which form a very valuable part of the hay.

## HEAVY SEEDED MIXTURES OF SOY BEANS AND COWPEAS

In Table XII. it is seen that soy beans sowed broadcast at the rate of 10 pecks per acre gave an average yield of 2467 pounds of cured hay per acre. By mixing 5 pecks of soy beans with 5 pecks of whippoorwill cowpeas and sowing them broadcast the yield of cured hay was increased 203 pounds per acre. When the amount of soy beans mixed with 5 pecks of cowpeas was reduced from 5 to 3 pecks, the average yield of hay was slightly increased— 280 pounds per acre. A mixture of 5 pecks of Mammoth Yellow beans and of three pecks of Iron cowpeas gave an average increase of 352 pounds of hay over the yield of 10 pecks of soy beans planted alone.

In Table XII. it is shown that 10 pecks of Mammoth Yellow soy beans alone sown broadcast did not yield per acre 467 pounds as much cured hay as 10 pecks of Whippoorwill cowpeas planted in a similar way. When the rate of seeding of soy beans was reduced from 10 to 7½ pecks per acre, the yield of hay fell off 329 pounds per acre.

TABLE XII.—*Heavy Seeded Mixtures of Soy Beans and Cowpeas for Hay*

| Varieties                                     | Amount of seed<br>per acre | How planted | Yield cured hay per acre |      |      |      |          | Increase of<br>Averages |
|-----------------------------------------------|----------------------------|-------------|--------------------------|------|------|------|----------|-------------------------|
|                                               |                            |             | 1910                     | 1911 | 1912 | 1913 | Averages |                         |
|                                               |                            |             | Lbs.                     | Lbs. | Lbs. | Lbs. | Lbs.     |                         |
| Mammoth Yellow Beans                          | 10 pks.                    | Broadcast   | 2464                     | 5488 | 2288 | 1495 | 2934     | Lbs.<br>467             |
| Mammoth Yellow Beans and<br>Whippoorwill Peas | 5 pks.<br>5 pks.           | Broadcast   | 2256                     | 5320 | 1488 | 805  | 2467     | ---                     |
| Mammoth Yellow Beans and<br>Iron Peas         | 5 pks.<br>3 pks.           | Broadcast   | 2200                     | 4640 | 1408 | ---  | 2747     | 280                     |
| Mammoth Yellow Beans and<br>Whippoorwill Peas | 3 pks.<br>5 pks.           | Broadcast   | 2336                     | 5200 | 2480 | 1260 | 2819     | 352                     |
| Mammoth Yellow Beans                          | 10 pks.                    | Broadcast   | 2196                     | 5860 | 1200 | 1425 | 2670     | Lbs.<br>203             |
| Whippoorwill Peas                             | 10 pks.                    | Broadcast   | 2256                     | 5320 | 1488 | 805  | 2467     | ---                     |
| Mammoth Yellow Beans                          | 7½ pks.                    | Drilled     | 1744                     | 4540 | 1392 | 875  | 2138     | 329                     |

## LIGHT SEEDED MIXTURES OF SOY BEANS AND COWPEAS

Soy beans planted broadcast at the rate of 64 pounds per acre gave an average yield of 1252 pounds of cured hay and Iron cowpeas seeded at the same rate and manner gave an average yield of 2546 pounds per acre, or an increase of 1602 pounds. When 48 pounds of Mammoth Yellow soy beans were mixed with the same weight of Iron cowpeas and sowed broadcast, the average yield of cured hay was 2868 pounds per acre— an increase of 1616 pounds over the yield from the seeding of 64 pounds of soy beans alone or an increase of 322 pounds over the yield from the seeding of 64 pounds of Iron cowpeas.





When 64 pounds of soy beans was planted in the drill and cultivated two or three times, the yield of hay was 1368 pounds per acre; when 61 pounds of Iron cowpeas was planted in the same way and given the same treatment, the yield of hay was 2970 pounds per acre; but when 48 pounds of soy beans was mixed with the same amount of Iron cowpeas and planted together, the average yield of hay was only 2315 pounds per acre.

When the rate of seeding soy beans is reduced to about one bushel per acre, a wide difference in yield between soy beans and cowpeas is observed. The average yield of hay from 64 pounds of Iron cowpeas per acre was greater by 1294 pounds than from the same amount of soy beans. When planted in drill and given two cultivations, the cowpeas exceeded the soy beans by an average of 1602 pounds.

Cowpeas, being a vine plant, covered the ground and choked out grass and weeds, while the soy beans, being an erect plant, permitted the grass and weeds to grow and was itself choked by them. To secure the maximum yield and quality of hay from soy beans, the seeding must be on good soil and sufficiently thick to keep down weeds.

The advantage of drilling soy beans for hay comes from freedom of weeds and an improved quality of hay. On strong land the same results to some degree are secured from thick, broadcast seeding of beans.



Well Inoculated Plants—Nodules  
Growing Even On the Shaded  
Surface of the Soil

## THE SOY BEAN AS A SOIL IMPROVING CROP

The importance of the soy bean as a nitrogen gatherer and a soil improvement crop is scarcely less than that of the cow-pea. Even when the crop is harvested for hay or seed, the amount of nitrogen in the soil is not reduced, as in the case of a corn crop, but is considerably increased. It leaves the land in a splendid physical condition for any following crop.

The value of the soy bean crop toward maintaining soil fertility is increased when it is harvested by stock or when it is fed and the manure returned to the land. The easy method of harvesting by pasturing and the increased fertility of the land should not be overlooked by farmers.

The comparative fertilizing effect of a corn crop, cowpeas and soy beans drilled and cultivated when followed by a cotton crop is shown in the following table:

TABLE XIV. *Comparative Fertilizing Effect of Soy Beans, and Corn on a Succeeding Cotton Crop*

| Yield of seed cotton per acre. |      |      |          |                         |
|--------------------------------|------|------|----------|-------------------------|
| Crops                          | 1911 | 1914 | Averages | Increase due to legumes |
|                                | Lbs. | Lbs. | Lbs.     | Lbs.                    |
| After Corn                     | 1303 | 979  | 1141     | —                       |
| After Cowpeas                  | 1890 | 962  | 1426     | 285                     |
| After Soy Beans                | 1910 | 1008 | 1459     | 318                     |

Only the grain from the corn, cowpeas and beans were harvested. All the stover and straw of the corn, cowpeas, and soy beans were left on the land and plowed under the next spring for soil improvement.

Cotton followed corn, cowpeas, and soy beans, and received no nitrogenous fertilizer.

From the corn land the average yield of seed cotton was 1141 pounds per acre; from the cowpea land, 1426 pounds; and from the soy bean land, 1459 pounds. The cowpea land gave an average increase over the corn land of 285 pounds, and the soy beans land an average increase of 318 pounds. In money value, the fertilizing benefit from the cowpeas to the following cotton crop, if the seed cotton be calculated at 4 cents a pound, was \$11.40 and from the soy beans \$12.72 per acre.

In 1909 a mixture of Crimson Clover and Red Rust Proof oats, of Crimson Clover and Blue Stem Wheat, and of Crimson Clover alone were planted after corn, cowpeas, and soy beans. The yield of cured hay is shown in the table below:

TABLE XV. *Comparative Fertilizing Effect of Soy Beans, Cowpeas and Corn on a Following Hay Crop*

| Yield of cured hay per acre |                                        |                                    |                |                    |                         |
|-----------------------------|----------------------------------------|------------------------------------|----------------|--------------------|-------------------------|
| Crops                       | Red Rust Proof Oats and Crimson Clover | Blue Stem Wheat and Crimson Clover | Crimson Clover | Average of 3 kinds | Increase due to legumes |
|                             | Lbs.                                   | Lbs.                               | Lbs.           | Lbs.               | Lbs.                    |
| After Corn .....            | 4373                                   | 3512                               | 2289           | 3391               | -----                   |
| After Soy Beans .....       | 5137                                   | 4722                               | 2889           | 4249               | 858                     |
| After Cowpeas .....         | 4709                                   | 5305                               | 2791           | 4268               | 877                     |

In the above table it is noticed that the average yield of hay following cowpeas and soy beans is 877 and 858 pounds greater respectively than when it follows corn. When the hay was valued at \$15.00 a ton, the fertilizing effect of the cowpeas was \$6.56 per acre, and of soy beans \$6.43.

In 1906 an experiment was conducted to secure data on the fertilizing effect of corn, cowpeas, and soy beans on a succeeding winter oat crop. The increase in yield of oats due to cowpeas, even where the seed had been picked, was about 300 per cent over the yield from the corn land. The increase in oats due to soy beans, which were gathered in such a way as to leave only the stubble, was 173 per cent over the yield from the corn land.

The Ohio Experiment Station found that the average yield of wheat following soy beans was 10.3 bushels greater than that following corn.\*

#### COMPARATIVE YIELD OF GRAIN FROM SOY BEANS, CORN AND COWPEAS

The comparative yield of grain from corn, cowpeas, and soy beans is shown in Table XVI. These crops were planted at the same time, fertilized alike, and received

(\*See p. 592 bul. 312, Ohio Agri. Experiment Station.)



good culture. In each case the grain was carefully harvested and weighed, and in the table is recorded the actual weight of grain or seed not including the weight of husks, cowpeas and soy bean hulls.

TABLE XVI.- *Comparative Yield of Grain Per Acre of Corn, Cowpeas, and Soy Beans.*

| Crops           | 1908 | 1909 | 1910 | 1913 | 1914 | 1915 | 1916 | 1917 | Av.  |
|-----------------|------|------|------|------|------|------|------|------|------|
|                 | Lbs  | Lbs  | Lbs  | Lbs  | Lbs  | Lbs  | Lbs  | Lbs  | Lbs  |
| Corn .....      | 1664 | 1572 | 1604 | 2294 | 464  | 1322 | 1699 | 2800 | 1677 |
| Cowpeas .....   | 1020 | 1080 | 870  | 432  | 320  | 530  | 920  | 1318 | 811  |
| Soy Beans ..... | 864  | 500  | 805  | 423  | 376  | 700  | 1084 | 1019 | 721  |

In the column of averages it is noticed that the pounds of shelled corn per acre more than doubles the pounds of soy beans or cowpeas. If the legumes are grown only for their grain, their yield does not compare favorably with corn as a grain crop.

The analysis of the soy bean grain shows that it has about four times as much digestible protein, one-third as much carbohydrates, and over three times as much fat as corn grain. Soy beans or soy bean meal, fed as a supplement with corn to growing stock or those requiring a high protein ration, produce a gain about equal to that obtained from the feeding of equal amounts of shorts, tankage or cottonseed meal in combination with grain. For dairy cattle, ground soy beans show a slightly higher feeding value than cotton seed meal.\* In feeding experiments of fattening hogs, soy beans supplemented with corn gave about the same gain that was secured from feeding tankage and corn.\*\*

When one considers the fertilizing effect of a crop of soy beans on the land for any following crop, and the ease with which the crop is grown and the high feeding value of the bean as a concentrated feed, the true value of the corn and the bean crop to the farmer may be seen in its real light.

#### ENEMIES OF THE SOY BEAN

Probably the greatest enemy to the growing of the soy bean is rabbits. They are very fond of the young, green, tender foliage. Where only a small patch is planted, the rabbit has been known to destroy it entirely. It is suggested that the farmer plant enough for the rabbits and for the farm.

\*Tenn. Bul. No. 80.

\*\*Ind. Bul, 126, 137.



Diseased Soy Bean Root Showing the Effects of Nematodes

A very small eel-like worm, called nematode, (*Heterodera radicicola*) sometimes attacks the soy bean root and causes irregular enlargements on it. The enlargements are mistaken by some for nodules caused by nitrogen - gathering bacteria, peculiar to this plant. Where the soil is badly infested with this insect, the farmer is advised to plant some other crop that is not susceptible to its attack.

The soy bean suffers from a disease that attacks the underground part of the plant and causes the leaves and stem to wilt. When the plant is examined, it is noticed that the bark is soft, and the woody part of the stem dark. This darkening of the stem is due to a microscopic fungus (*Fusarium trocheiphilum*-Smith), which is said

to be the same organism that produces the wilt of cowpeas. When a field becomes infested with this disease, it should not be planted in soy beans or cowpeas susceptible to wilt.

Root rot attacks the soy bean plant and causes a wilting of the leaves, followed by the death of the entire plant. When the plant is pulled up, a mat of white fluffy mold is usually found on the stem directly below the point where the stem enters the ground. On

it may later appear small round bodies (sclerotia) which perpetuates the fungus.

Leaf spot sometimes appears when the plants have about reached maturity. It does not do much injury.

#### BRIEF DESCRIPTION OF THE COMMON VARIETIES OF SOY BEANS

ACME 14954.—This is a medium late variety. The plants range from 25 to 36 inches in height. The stems are semi-vined with 3-6 slender lateral branches almost as high as the main stems. The pods bear from 2 to 3 beans. This is a prolific variety.

ARLINGTON 22899.—This is a medium early variety. The color of the bloom is purple. The plants range from 36 to 48 inches in height. The stem is fine, moderately erect, and has many long ascending branches. The leaflets are large heart shaped and furnish an abundant foliage. The pods are 2 to 2½ inches in length, yellowish and very fuzzy; the seed remain in the pods until they are fully ripe and the over-ripe pods do not shatter badly when they are harvested.

AUSTIN 17263.—This is an early variety with white blooms. The plants range about 30 inches in height with numerous bunchy and woody stems. The leaflets are broad at base and pointed. Its seed is rather large and yellow.

BAIRD.—This is an early variety. The beans are small and reddish. The plants range from 15 to 20 inches in height. The stems are small and upright and have very few lateral branches. Its leaves are small and subject to a brown rust and early shedding. It is not a promising variety.

BARCET 23232.—This is a late semi-vine variety, later than the Mammoth Yellow. The color of the bloom is pinkish. The plants are slender and vary from 32 to 40 inches in height and send out from 2 to 6 lateral vine-like branches as tall as the main stem. Its pods are small brown or blackish and do not shatter when over-ripe. It is a promising variety for a late hay crop.

BLACKBEAUTY.—This is a medium early, black-seeded variety. The stem and branches are slender and erect with a tendency to twine when grown on fertile land. It is leafy and retains them well until its pods are ripe. Its pod stems are very short and do not grow in large clusters; its flowers are pink or purple; and its seed are black.

BILOXI.—The stem is strong, woody, making a rank growth that resembles Mammoth Yellow. It varies from 40 to 48 inches in height, and is erect and easy to mow. Its pods are brown and very fuzzy; and its seed are brown and medium size. It is a good variety for seed and hay, if planted early.

CHINESE 20797.—This variety is very late. The bean is small and dark in color and does not shatter badly. The stems range from 36 to 45 inches, all vine-like but strong enough to give them an upright form and make the mowing for hay easy. The leaves are small and abundant. The variety is promising for hay but not for seed.

**EBONY.**—This is a small black seeded medium late variety. On good soil the stems have a tendency to twine. It has both purple and white blooms. The leaves are small, dark and crimped. The pod is very small, and contains two or three black seed. This variety is promising as a hay crop and yields seed well.

**EDWARD SOY.**—Under this name is described a late variety resembling Mammoth Yellow. The plant varies from 30 to 40 inches in height, having a strong woody upright stem with many strong upright lateral branches bearing fruit. The pods are large, containing two or three yellow beans. This makes a good variety for hay and seed in the Gulf States.

**HABERLANDT.**—This is a low medium early variety with coarse, stiff plants, having a tendency to branch heavily but not to twine. Its seed grow close about the stems which makes it somewhat difficult to harvest. It is a good variety for seed production.

#### HOLLYBROOK 17278

—Hollybrook is about two weeks earlier than the Mammoth Yellow. Its blooms are white; its seed medium in size and yellow. The plants are slender and range from 24-36 inches in height. Generally there is only one main upright woody stem, and very few lateral branches. The pods are small with two or three beans to the pod. This variety is not very desirable for hay but makes heavy yields of seed.

**ITO SAN SOY**—This is a well known very early variety. The seed is similar in size and color to the Mammoth Yellow. The plants are medium size, about 11 to 16 inches in height, erect in habit, with coarse stems. This is an excellent variety to use where very early grain is wanted.



Hollybrook Plant

**MAMMOTH YELLOW.**—Mammoth Yellow sometimes called mammoth, is a late variety requiring 120 to 130 days to mature seed. The plants range from 27 to 36 inches in height. The stems are rather coarse, erect, and woody, having many rather stiff lateral fruit bearing branches. Its abundant leaves are large, dark, and crinkled; its flowers white. The pods are



fuzzy, and yellow when ripe, bearing two or three medium size, yellow beans. This variety makes a satisfactory crop of both seed and hay, and being a rank growing variety may be used very satisfactorily for a green manure crop. It is well adapted to the Gulf States.

**OTOOTAN.**—This is a very late variety. The plants vary from 40 to 45 inches in height. The stems are rather fine, almost vine-like with considerable tendency to lodge when the plants are about grown. The branches spring out from 4 to 6 inches above the ground, an advantage in mowing. It has an abundance of leaves and cures readily. Its pods are brown and fuzzy and have two or three large brown beans. It is a promising variety for hay production and soil improvement.

**PEKIN 152.**—The variety is early. The blooms are white and purple. The plants range from 24 to 36 inches in height. The plant is perfectly erect with rather fine stem and small, pale yellow foliage. This variety ranks well both as a seed and as a hay crop. The seed is black and small. There is practically no loss of seed from shattering.

**RUELAND 20797.**—This is a very late variety. The plants range from 36 to 40 inches in height. The stems are vine like, barely strong enough to give an upright form to the plants. The leaves are medium in size, and heart shaped. The beans are dark and small and do not shatter from the pods. This is a promising variety for hay.

**SHANGHAI 14952.**—This is a medium early variety. The plants range about 30 inches in height. The stems are strong,



Plants of Three Leading Varieties. From Left to Right:  
1. Barchet; 2. Arlington; 3. Mammoth Yellow.





Plant of Wilson Variety

upright and woody; bearing rather weak lateral branches. The pods are medium to large and covered with brown fuzz. This variety proved to be promising.

**SWAN 22379**.—This is a promising early variety. The blooms are white in color. The plants range from 20 to 30 inches in height. The stems are bunched. The leaves are medium in size and heart-shaped.

**TOKYO 17267**.—This is a medium early variety. The bloom is purple and appears about August 10 to 15. The plants range from 12 to 15 inches in height. The stems are low, woody, and spreading, and bear many lateral branches. The pods are medium in size and have two or three large green beans per pod. This is a promising dwarf variety.

**VIRGINIA 32906**.—It is an early variety. The color of the bloom is purple. The stem is semi-vine like, and beans small. This variety is good for hay.

**WILSON (BLACK) 19185**. — This is an early variety, the stem ranging from 36 to 40 inches in height. The stems are fine and erect with long ascending branches. Only a few of the branches are near the ground, which is an advantage in mowing. This variety makes abundant foliage and a fair production of seed. The seed is black and medium in size.



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**JUNE, 1918**

TECHNICAL BULLETIN No. 5

**ALABAMA**  
**Agricultural Experiment Station**

OF THE

**Alabama Polytechnic Institute**

**AUBURN**

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**The Destruction of Vanillin in the Soil  
by the Action of Soil Bacteria**

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By

**WILLIAM J. ROBBINS**

Assisted by A. E. Elizando

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1918

Post Publishing Company  
Opelika, Ala.

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# THE DESTRUCTION OF VANILLIN IN THE SOIL BY THE ACTION OF SOIL BACTERIA

By

WILLIAM J. ROBBINS

Assisted by A. E. ELIZANDO

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In an earlier publication (6)\* it was concluded that the addition of a given toxic organic compound may produce no harmful effects in one soil and decidedly harmful effects in another, depending on the presence and action of suitable microorganisms which destroy the toxic compound. In the present paper further evidence is offered to justify the application of this conclusion to a number of soils in which the effect of vanillin on the growth of higher plants has been tested. Vanillin is an aldehyde which is harmful in water culture at a concentration of 1 part per million (7) to wheat plants, and which has been isolated from unproductive soil (8). The writer has shown (6) that in certain Alabama soils it is rapidly destroyed by the action of bacteria.

## THE PRESENCE OF VANILLIN-DESTROYING BACTERIA IN SOILS OTHER THAN ALABAMA SOILS

Four investigations in addition to the one carried on at the Alabama Experiment Station (5) have been made on the effect of the addition of vanillin to the soil on the growth of plants. Davidson (2) working at the New York State College of Agriculture found that vanillin had little bad effect on the growth of wheat. Skinner (9) in field tests at the experiment farm of the Agricultural Department at Arlington, Virginia, found that vanillin stunted the growth of cow peas, garden peas and string beans. He found vanillin present in the soil of these plots six months after its application. The same investigator in pot experiments found vanillin to be harmful to wheat plants grown in infertile Florida sandy loam but to have no effect in fertile Hagerstown loam. Fraps (4) at College Station, Texas, found in general little harmful effects from the application of vanillin to potted soil. He also found that the vanillin rapidly disappeared during the course of the experiment. Upson and Powell (10) at Lincoln, Nebraska, report that vanillin shows very little

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(\* Reference is made by number to Literature cited p.)



harmful effect in the soil on the growth of wheat.

From the above brief review it can be noted that Davidson, Fraps and Upson and Powell found little harmful effect from the addition of vanillin to the soil. Skinner also found vanillin to have little or no effect when added to the fertile Hagerstown loam. He obtained, however, marked bad effects in the Arlington soil, in the infertile Florida sandy loam and in the infertile Susquehanna sandy loam.

From our own work on Alabama soil we assume that the results first cited where little harmful effect was observed were due to the fact that bacteria which fed on vanillin were present and the soil conditions were suitable for their growth and their destructive action on vanillin. On the addition of vanillin to these soils the bacteria destroyed the vanillin and little or no bad effect resulted. The results in the Arlington soil, in the Florida sandy loam and the Susquehanna sandy loam would be explained as due either to the absence of suitable bacteria or to conditions in those soils which prevented the growth and the action on vanillin of the bacteria. Under either of these conditions the added vanillin would persist and evidence its toxicity. To demonstrate the correctness of this view samples of all the above soils except the Hagerstown loam, Florida sandy loam and Susquehanna sandy loam have been examined for the presence of vanillin-destroying bacteria. In addition the effect of vanillin on the numbers of microorganisms in the Arlington soil has been studied.

Through the courtesy of Dr. T. L. Lyon of the New York State College of Agriculture a sample of soil was received from the same field and as nearly as could be determined from the same spot as that used by Davidson in the experiments noted above. This soil was collected with a sterile spoon and shipped by express in a sterile can. Upon its receipt, using all precautions to avoid contamination, a small quantity was added to a sterile nutrient solution containing vanillin.<sup>2</sup>

<sup>2</sup>This solution contained:

|                                       |         |
|---------------------------------------|---------|
| Na NO <sub>3</sub> .....              | 0.1 gm. |
| K <sub>2</sub> HPO <sub>4</sub> ..... | 0.1     |
| Mg SO <sub>4</sub> .....              | 0.05    |
| NH <sub>4</sub> Cl .....              | 0.1     |
| KCl .....                             | 0.05    |
| Vanillin .....                        | 0.1     |
| Water Dist. ....                      | 200 cc. |

The solution soon became cloudy and within a few days a test for vanillin using the acid nitrate of mercury reagent described by Estes (3) showed that the vanillin had disappeared. The cloudy solution was plated out and from the isolations made, bacteria were obtained which, in pure culture, destroyed vanillin.

By the kindness of Dr. G. L. Fraps four of the soils used by him in his work with vanillin were collected and shipped in sterile cans. The four soils were those referred to in his publication (4) as Nos. 876, 870, 1956 and 114. All four of the soils contained vanillin destroying bacteria.

From Dr. F. W. Upson the Black Meadow soil and Lancaster fine sandy loam referred to in the work by Upson and Powell cited above were received. These soils were also collected and shipped under sterile conditions. The presence of vanillin-destroying bacteria in these two soils was also demonstrated and pure cultures of vanillin-destroying bacteria isolated from them. With these soils there was also forwarded a can of what appeared to be quartz sand in regard to which Dr. Upson stated.

"We get a very marked difference between the sand and the two soils in regard to their ability to destroy vanillin and cumarin."

In this sand no organisms destroying vanillin could be demonstrated.

Through the kindness of Dr. Oswald Schreiner and Dr. J. J. Skinner, a sample of the Arlington soil was received. This sample was collected and shipped under sterile conditions. Vanillin-destroying bacteria were found to be present in this soil and were isolated in pure culture.

We have, therefore, demonstrated the presence of vanillin-destroying bacteria in those soils to which the addition of vanillin has been found to have little bad effect on the growth of plants. The sand is of much interest as here we apparently have a case in which the vanillin persists and evidences its toxicity because of the absence of vanillin-destroying bacteria. The Arlington soil is also of much interest because in this case the vanillin persists and is toxic even though vanillin-destroying bacteria are present in the soil. We, therefore, assume that conditions are not suitable in this soil for the growth and the action of the vanillin-destroying bacteria present. To test the correctness of

this assumption the effect of the addition of vanillin to this soil on the number of microorganisms in it was determined.

EFFECT OF THE ADDITION OF VANILLIN TO THE ARLINGTON  
SOIL ON THE NUMBER OF MICROORGANISMS  
DEVELOPING IN IT

As was pointed out in a previous publication (6) the addition of vanillin in suitable concentration to a soil in which the vanillin-destroying bacteria are present and are under conditions which allow them to act produces an initial decrease in the number of microorganisms present which will develop on Brown's albumen agar (1). This decrease is followed by a marked temporary increase in the number as the vanillin-destroying bacteria feed on the vanillin and multiply. With the exhaustion of the vanillin and its decomposition products the number of microorganisms returns to normal. By studying, therefore, the effect of vanillin on the number of microorganisms in the Arlington soil it was hoped that an indication might be found as to whether the conditions in that soil are suitable for their action on vanillin.

Dr. Oswald Schreiner was kind enough to furnish us with a quantity of the Arlington soil. The soil as received was very acid having a lime requirement by the Veitch method of 4740 pounds per acre.

Nine kilograms of the air dry soil were placed in two-gallon pots and the pots were brought to the optimum water content with distilled water. At the same time nine kilograms of air dry Norfolk sandy loam from the station farm were placed in two-gallon pots. This soil was practically neutral, having a lime requirement of 600 pounds per acre. It was also brought to optimum water content with distilled water. After standing 30 days the soil from two pots of the Arlington soil was removed, mixed with a sterile spatula on sterile paper and repotted. These served as checks. The soil from two other pots was similarly treated but 9 gms. of vanillin was added to each pot. The soil from two additional pots was removed, 9 gms. of vanillin added to each pot and the soil well inoculated with a suspension of a pure culture of a vanillin-destroying bacterium isolated from Alabama soil. Two pots of the Norfolk sandy loam were prepared as checks and two pots of the same soil were prepared to each of which 9 gms. of

vanillin were added. From time to time the number of microorganisms developing in the pots was determined by the methods described by Brown (1) using his albumen agar. Each soil was plated in duplicate using dilutions of 1-20,000 and 1-200,000 as described by Brown. The number of microorganisms developing in the pots is given in Table 1.

TABLE 1

*Microorganisms in Millions per gm. of Air Dry Soil.  
Soil Potted June 5th, Vanillin Added July 5.*

| Treatment                                             | June 15 | June 26 | July 9, 4 days<br>after treatment | July 18, 13 days<br>after treatment | July 27, 22 days<br>after treatment | Aug. 4, 30 days<br>after treatment | Aug. 17, 43 days<br>after treatment | Aug. 31, 57 days<br>after treatment |
|-------------------------------------------------------|---------|---------|-----------------------------------|-------------------------------------|-------------------------------------|------------------------------------|-------------------------------------|-------------------------------------|
| None—Arlington Soil                                   | 4.74    | 7.32    | 1.52                              | .92                                 | 2.52                                | 4.76                               | 5.49                                | 2.66                                |
| Vanillin—Arlington Soil                               | 14.92   | 10.26   | 0.12                              | 0.18                                | 0.05                                | 0.14                               | 0.14                                | 0.96                                |
| Vanillin & Van.-destroying<br>bacteria—Arlington soil | 8.12    | 4.46    | 0.11                              | 0.06                                | 0.00                                | 0.14                               | 0.21                                | 0.32                                |
| None—Alabama soil                                     | 9.76    | 8.83    | 7.88                              | 4.98                                | 8.26                                | 4.45                               | 5.45                                | 3.76                                |
| Vanillin—Alabama soil                                 | 11.48   | 8.16    | 1.28                              | 5.76                                | 22.22                               | 22.44                              | 14.68                               | 18.12                               |

The data in Table 1 indicate that the persistence of vanillin in the Arlington soil is due to some condition or conditions which prevent the destructive action on vanillin of the vanillin-destroying bacteria. As was found before (6) the addition of vanillin to the Alabama soil first produces a decrease in the number of microorganisms which will develop on Brown's albumen agar. This decrease is followed by an increase in which the numbers far exceed those present in the normal soil. There is then a return to normal. In the Arlington soil, however, no such phenomenon occurs. The addition of vanillin produces a marked decrease in the numbers but this is not followed by any increase. In fact, as far as bacteria are concerned, the upper layers of soil remain practically sterile as the majority of microorganisms indicated in the table as developing in the vanillin treated Arlington soil were molds. Only occasional bacterial colonies appeared on the plates from these pots. Even the addition of a pure culture of a bacterium known to destroy vanillin does not im-



prove conditions as can be noted from the table. There can be no question regarding the persistence of vanillin in this soil. It rose to the surface of the soil where it was observed in crystals more than 40 days after its addition to the pots. It is, therefore, believed that the persistence of vanillin in the Arlington soil is due to conditions in that soil which prevent the action of the bacteria on the vanillin.

What these conditions are can not be definitely stated at the present stage of the investigation. The soil, as was indicated above, is very acid. It was found, however, that in an acid Alabama sandy loam, having a lime requirement of 3400 pounds per acre, vanillin, at the same concentration as was used in the Arlington soil, was entirely destroyed in less than 57 days (6).

Soil extracts of Alabama soil and Arlington soil to which vanillin was added showed no difference in the rate at which vanillin was destroyed by a pure culture of a vanillin-destroying bacterium.

It is possible that the persistence of vanillin in this soil is due to poor oxygenation conditions. It has been found that oxygen seems to influence the rate at which vanillin is destroyed by a pure culture of a vanillin-destroying bacterium and the destruction of vanillin by this organism is an oxidative process, at least in its early stage. The Arlington soil is a heavy silty clay loam which compacts easily, probably excluding oxygen to a large measure.

Some condition which may be poor oxygenation is certainly unfavorable for bacterial growth in this soil. This can be seen from the fact that, as is indicated in Table 1 in the data for the check pots, the mere removal, mixing and repotting caused a marked decrease in the numbers of bacteria found 4 days later. This decrease is perhaps best explained as a dilution effect. If we assume that the upper layer of soil contained numerous bacteria, while in the lower reaches of the soil the bacteria which will develop on plates under aerobic conditions were few or absent, then in mixing the soil as was done at the time of treatment there would be a decrease in the numbers because those bacteria in the upper layers were spread through the contents of the entire pot. Not only is this decrease evident 4 days later, but it continues to be evident for something over 22 days as it is not until 30 days after



treatment that the numbers of bacteria in the untreated Arlington soil approach normality. This seems, perhaps, to be slower than would be expected if oxygen were the limiting factor in the multiplication of the bacteria. In the untreated Alabama soil which is a porous sandy loam no decrease in numbers is produced by the mixing and repotting.

A further investigation of soils in which vanillin has been found to persist, to determine whether bacteria capable of destroying vanillin are present and if they are, to determine why they do not act on the compound is advisable.

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ALABAMA  
Agricultural Experiment Station

OF THE

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AUBURN

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Variety Tests of Wheat

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By

E. F. CAUTHEN

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1918

Post Publishing Company,  
Opelika, Ala.



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# VARIETY TESTS OF WHEAT

By  
E. F. CAUTHEN

Owing to the urgent need of wheat to meet the conditions that have grown out of the European War, the farmers of Alabama are advised to increase the wheat acreage—especially where the land is fairly well adapted to this important crop. They are advised to sow wheat not as a money crop, but to supply their own farm needs with wheat bread. To grow it is the only sure way for Alabama farmers to have a supply next year.

Experiments with varieties of wheat have been made almost continuously for 20 years on the Alabama Experiment Station farm at Auburn. They show that a reasonable crop may be expected almost every year when planted under conditions like those here. The fertilizer per acre applied at planting time usually consisted of 240 pounds of acid phosphate, 160 pounds of cotton seed meal and 160 pounds of kainit, or its equivalent of potash in some form, per acre. Between March 10 and 25 a top dressing of 100 pounds of nitrate of soda per acre was usually given.

Some years the wheat was planted on cowpea stubble; other years, on cotton or corn land. In all cases the land was plowed well, seed sown broadcast by hand, and covered about two inches deep with a disk harrow.

The varieties of seed were obtained from different sources and planted at the rate of one bushel per acre. The average date of planting for the last 10 years was November 11; the average date of harvesting for the same period of years was May 29 for all varieties except the Alabama Blue Stem, which was harvested about 10 days earlier.

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\*This bulletin contains the results of the variety tests reported in bulletin No. 179 and similar data that have accumulated since its publication.

TABLE I.—*Varieties of Wheat: Yields at Auburn in Bushels per acre*

| Variety                                    | 1899 | 1901 | 1902 | 1903 | 1906 | 1907 | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1918 | Av.  |
|--------------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Alaska                                     | ---  | ---  | ---  | ---  | ---  | ---  | 12.6 | 6.4  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  |
| Acme                                       | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 14.5 | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  |
| Beardless Fulcaster                        | 6.5  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  |
| Blue Stem or Purple Straw<br>from seedsmen | 4.   | 11.3 | 15.7 | ---  | 21.1 | 1.7  | 24.8 | 17.6 | 15.6 | 9.1  | 10.4 | 34.9 | 14.6 | 12.1 | 14.2 | 13.9 | 14.8 |
| Blue Stem or Purple Straw                  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  |
| Alabama Strain                             | ---  | 18.3 | 16.5 | 7.8  | 23.2 | 7.0  | 24.3 | 19.9 | 19.2 | 14.4 | ---  | 31.5 | 13.1 | 16.8 | 17.0 | 14.0 | 15.9 |
| Currell                                    | ---  | 16.6 | 13.7 | 6.8  | ---  | 3.7  | 23.5 | 19.8 | ---  | ---  | ---  | ---  | 13.7 | 12.4 | ---  | ---  | 14.0 |
| China Wheat                                | ---  | ---  | 16.8 | ---  | ---  | ---  | ---  | ---  | 15.1 | 8.5  | ---  | ---  | 13.4 | 16.9 | 17.4 | 15.0 | 14.6 |
| Deitz or Deitz Mediterranean               | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  |
| Fultz                                      | 7.4  | 16.5 | 15.0 | 6.5  | 20.0 | 2.4  | 20.7 | 15.6 | ---  | ---  | 14.0 | ---  | 14.4 | 16.4 | 13.9 | 13.9 | 16.3 |
| Fulcaster                                  | 5.8  | 17.0 | 18.1 | 6.1  | 17.0 | 4.6  | 23.2 | 15.6 | 14.1 | 9.8  | 13.1 | 29.5 | 11.5 | 12.8 | 17.9 | 12.1 | 13.0 |
| Fultz Mediterranean                        | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 12.6 | ---  | ---  | ---  | ---  |
| Fultz No. 1923                             | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  |
| Golden Chaff                               | ---  | 15.5 | ---  | 6.8  | 20.0 | 4.6  | 21.6 | 22.2 | 17.1 | 6.5  | 12.4 | 34.0 | ---  | 16.6 | 13.4 | 16.2 | 15.9 |
| Harvest King                               | ---  | ---  | ---  | 4.6  | ---  | ---  | ---  | ---  | ---  | ---  | 12.9 | ---  | ---  | ---  | ---  | ---  | ---  |
| Klondyke                                   | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  |
| Lancaster                                  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 8.6  | 6.6  | ---  | ---  | ---  | ---  | 14.4 | ---  | ---  |
| Leap                                       | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 12.2 | 28.1 | ---  | ---  | 12.5 | ---  | ---  |
| Leap No. 4823                              | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 18.0 | 6.7  | 11.0 | 25.6 | 12.3 | 17.2 | ---  | 13.8 | 14.6 |
| Monarch                                    | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 14.1 | ---  |
| Macaroni                                   | ---  | ---  | 16.2 | 4.5  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  |
| Red May (or Early May)                     | ---  | ---  | ---  | ---  | 19.1 | 2.2  | 22.7 | 21.9 | 15.4 | 7.5  | 11.4 | ---  | ---  | 12.8 | ---  | ---  | ---  |
| Red Wonder                                 | 5.4  | 17.0 | 12.0 | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  |
| Stoner or Miracle                          | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 17.2 | 9.0  | 16.0 | 26.1 | 13.8 | 18.1 | 16.9 | 17.0 | 16.9 |
| Velvet Chaff                               | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 28.4 | 14.1 | 16.5 | 15.5 | 14.4 | 17.8 |
| Average Yields—All Varieties               | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  |
| Busbels per acre                           | 5.9  | 16.3 | 15.5 | 6.2  | 20.1 | 3.7  | 21.7 | 17.4 | 15.5 | 8.7  | 12.8 | 30.4 | 13.2 | 15.4 | 15.3 | 14.3 | ---  |

TABLE II.—Varieties of Wheat Planted Four or More Years; Yields in Comparison with that of Fulcaster, Taken as 100 per cent

| Years                                   | 1899 | 1901 | 1902 | 1903 | 1906 | 1907 | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1918 | Av. | Rank of Avs. |
|-----------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|--------------|
| Variety                                 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |     |              |
| Blue Stem or Purple Straw from seedsmen | 69   | 66   | 89   | 124  | 124  | 37   | 107  | 113  | 111  | 93   | 79   | 118  | 127  | 95   | 75   | 115  | 95  | 9            |
| Blue Stem (Alabama Strain)              | ---  | 108  | 91   | 128  | 132  | 152  | 105  | 128  | 136  | 147  | ---  | 107  | 113  | 131  | 95   | 116  | 121 | 1            |
| Currell                                 | ---  | 98   | 76   | 111  | 126  | 80   | 101  | 127  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 103 | 6            |
| Deitz Mediterranean                     | ---  | ---  | 93   | ---  | ---  | ---  | ---  | 107  | 107  | 87   | 107  | ---  | 117  | 132  | 97   | 124  | 108 | 4            |
| Fultz                                   | 131  | 97   | 83   | 107  | 118  | 52   | 87   | 100  | ---  | ---  | 110  | 122  | 113  | 128  | 78   | 115  | 103 | 6            |
| Fulcaster                               | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100 | 7            |
| Golden Chaff                            | ---  | ---  | 86   | 111  | 118  | 100  | 93   | 142  | 121  | 66   | 95   | 115  | ---  | 130  | 75   | 134  | 107 | 5            |
| Leap                                    | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 128  | 68   | 84   | 87   | 107  | 134  | 70   | 114  | 99  | 8            |
| Red May or (Early May)                  | 93   | 105  | 66   | ---  | 112  | 48   | 98   | 140  | 109  | 77   | 87   | ---  | 122  | 126  | ---  | 104  | 99  | 8            |
| Red Wonder                              | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 122  | 92   | 122  | 88   | 120  | 141  | 94   | 140  | 115 | 2            |
| Stoner or Miracle                       | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | ---  | 96   | 123  | 129  | 87   | 127  | 112 | 3            |

TABLE III.—The Average Yield of all Bearded and all Beardless Varieties of Each Year

| Year      | 1899 | 1901 | 1902 | 1903 | 1906 | 1907 | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1918 | Av.  |
|-----------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Variety   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Bearded   | 5.8  | 16.5 | 17.5 | 6.1  | 20.0 | 4.6  | 16.7 | 15.6 | 14.5 | 9.1  | 13.8 | 28.0 | 13.2 | 15.8 | 16.4 | 14.6 | 14.2 |
| Beardless | 5.8  | 15.9 | 14.7 | 6.5  | 20.7 | 3.7  | 22.9 | 19.5 | 15.6 | 8.3  | 11.9 | 32.4 | 13.0 | 15.9 | 14.2 | 14.0 | 14.7 |

Table I shows the yield of grain of each variety each year that it was tested; also the average yield of grain of each variety tested four years or more. Of those tested four years or more, the yield ranged from 13.0 bushels to 17.8 bushels per acre.

The yield of all varieties was low in 1899, 1903, 1907, 1912—four lean years out of the 16 years of experimentation. A study of other crops, like cotton and corn, shows that they suffer lean years in about the same proportions. So the wheat grower should not expect a good crop each year.

To make a fair comparison between two varieties or a comparison of averages of varieties, the varieties should be grown the same year, on the same kind of soil, and receive the same treatment. By observing Table I, it is noted that some varieties were not continuous; therefore, their averages should be compared with those of varieties that were continuous.

Table II shows a comparison with Fulcaster of all varieties planted four or more years. The yield of Fulcaster each year is taken as 100 per cent, and the yield of each other variety is compared with it.

In the column of averages Blue Stem or Purple Straw (Alabama Strain) ranked first. The commercial Blue Stem or Purple Straw variety closely resembles it, except in earliness, and a comparison of yields shows that in only 3 years of the 13 that they were tested together did the commercial Blue Stem surpass the Alabama Strain in yield. The Alabama Blue Stem variety has been grown continuously in this section for a quarter of a century or more, and has become well adapted to the locality. Other varieties that rank closely to the Alabama Blue Stem are Red Wonder, Stoner or Miracle, Fultz Mediterranean and Golden Chaff.

#### BEARDLESS AND BEARDED TYPES

The varieties of wheat tested may be divided into two great classes—beardless and bearded. The following belong to the beardless class: Blue Stem or Purple Straw (both Commercial and Alabama Strains), Currell, Fultz, Golden Chaff, Leap, Red May, Klondyke, Velvet Chaff, Leap No. 4823; and the following to the bearded class: Acme, Fulcaster, Deitz Mediterranean, Alaska, Red Wonder, Lancaster and Stoner.



The question is sometimes asked, "Which produces the larger yield, bearded or beardless varieties?" The average yield of all bearded and of all beardless varieties of each year is shown in Table III.

During the first years of the tests only one or two bearded varieties were planted, but in later years the number of bearded varieties was nearly equal to that of the beardless. The difference in yield between bearded and beardless varieties is negligible.

The choice between a bearded and a beardless variety is a matter of convenience in handling and the use to which the straw is to be put. To the casual observer the bearded varieties in the field look more promising because the awns make the heads appear larger than those of beardless varieties. If a crop is to be harvested for hay instead of grain, a beardless variety is more desirable.

#### CULTURAL SUGGESTIONS

*Soils:* Wheat is not suited to poor land that is extremely sandy or poorly drained. It does best on loam, silt loam, and clay soils well supplied with humus. In the mountainous sections and the Tennessee Valley are considerable areas that are suited to the growth of wheat. In the Coastal Plain section the soils that are well supplied with vegetable matter will produce good crops under favorable seasons, even though they may be sandy.

*Preparation:* The land should be thoroughly plowed for wheat. The plowing should be done long enough before planting to allow the surface to become moderately well compacted by rainfall, rolling and repeated harrowing; but in case it cannot be done sufficiently early, the seed may be planted on a freshly plowed surface. Where corn or cotton stalks or pea-vines or velvet bean vines are present, they should be cut to pieces with a stalk-cutter or disk-harrow, so that the plows can turn them under completely.

Cotton and corn lands that are soft, mellow and free from a heavy cover of grass and weeds may be planted by sowing the seed and fertilizer broadcast and covering them with a disk-harrow or some other shallow cultivating implement. Land where the cotton was picked off early and the stalks destroyed to kill the boll weevil may be planted in the same way; but it is believed that most soils should be plowed in preparation for wheat, if time and labor will permit.

*Planting:* The time of planting should be early enough to allow the plants to get a good root system established before heavy freezes. Where the Hessian fly is present, it is recommended that the planting be postponed until after the first frost. Too early planting may cause the wheat to reach the booting stage before the danger of freezing has passed, but in case the wheat is growing into danger from a late freeze, it may be judiciously grazed in January or February. Do not graze the wheat when the ground is wet nor after the first of March.

The following dates of planting are suggested, though the planting may be two weeks earlier or later, depending upon the seasons and other factors: North Alabama, October 10 to November 1; Central Alabama, November 1 to 15; South Alabama, November 15 to 30.

Seed at the rate of four or five pecks per acre may be sowed broadcast and covered with a disk-harrow or some other shallow cultivating implement; or better it may be planted with an ordinary grain drill, if one is available. Planting with a grain drill is desirable, because it saves about one peck of seed per acre as compared with broadcast sowing and distributes the fertilizer with the wheat, thus economizing labor. The drills plant to a uniform depth and usually results in a more uniform stand.

All broken and shriveled grains and weed seed should be removed by running the seed through a fanning mill. If a fanning mill is not available, the seed may be fanned by dropping it in a current of air. Well cleaned seed has less disease and gives a better stand.

*Treatment for Smut:* The following treatment for stinking smut of wheat is recommended. "Soak seed for 10 to 20 minutes in an open tub containing a solution of 1 pint of formaldehyde to 40 gallons of water, or use one ounce to 2½ gallons. Forty gallons will treat 40 bushels.

Stir vigorously and skim off the refuse and grains rising to the surface.

After treatment drain off the solution, *dry immediately and thoroughly*, by spreading out the wet seed in a thin layer, and stirring occasionally.

Disinfect sacks, bins and drills to prevent reinfection."

\*Card I, E—Seed Treatment for Cereal Smuts, Department of Plant Pathology, Alabama Extension Service, Auburn, Ala.

*Fertilizer:* On most lands some form of nitrogen is essential. If it is not already in the soil, it should be put there in the most economical way—through the plowing under of cowpeas, or velvet beans, or red clover. When a good crop of these is plowed under as a preparation for wheat, 200 or 250 pounds of acid phosphate per acre is recommended at planting time, and in the early part of March a top dressing of 50 or 75 pounds of nitrate of soda, if available. Other forms of fertilizer containing nitrogen like calcium cyanamid or sulphate of ammonia may be used in its stead. When calcium cyanamid is used as a top dressing, its application should be made about March 1.

When wheat is planted on land that has had no leguminous crop plowed under for soil improvement and the amount of available nitrogen in the soil is small, 75 or 100 pounds of cotton seed meal with 200 pounds of acid phosphate per acre is recommended. They should be applied at planting time.

About every farm is some barnyard manure that can be used to supply a part of the nitrogen for the wheat. Six or eight tons scattered broadcast as a top dressing in the fall or early winter will greatly increase the yield and lessen the expense of buying commercial fertilizer. Where stable manure is used, it should not be applied too thickly, as it may cause a heavy growth of straw and consequently, lodging.

*Kind of Seed:* In Table I, is listed with their yields, the leading varieties that are adapted to Alabama conditions. They are the soft winter wheats. The hard red wheats grown in the northwest are not recommended for Alabama.

A variety that has been grown for several years in a locality and has done well is probably the safest to plant in that locality. The Blue Stem or Purple Straw marked Alabama Strain in Table I is one of those varieties that has become adapted to middle Eastern Alabama.

It is a smooth variety, about ten days earlier than the Blue Stem or Purple Straw, sold by most seedsmen and is recommended especially for Central and South Alabama. Seed of this variety is scarce and hence the choice must usually be made of one of the other standard varieties.

Other good beardless varieties are Fultz, Golden Chaff, Leap, Red May and Currell, and good bearded

varieties are Red Wonder, Fulcaster and Dietz. Seed of most of these varieties can be obtained from reliable southern seedsmen.

*Harvesting:* The best implement for cutting wheat is the binder. Where only a few acres are planted the wheat may be cut with a cradle and tied into bundles by hand. The bundles are shocked in the field and left there until they become dry.

If the community grows sufficient wheat to justify the buying of a thrasher, some farmer who has an engine will usually buy one and thrash for toll. The wheat can be fed to stock in sheaf in case no thrasher can be obtained. If no regular wheat mills are in the neighborhood, the wheat can be ground on a corn mill into good whole wheat flour. Five bushels of wheat make one barrel of white flour. Will you try to make sure of flour for next year? If so, plant some wheat this fall.

ALABAMA  
**Agricultural Experiment Station**

OF THE  
Alabama Polytechnic Institute  
AUBURN

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**Grazing Peanuts With Hogs**  
versus  
**Marketing A Crop of Peanuts**

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By  
GEO. S. TEMPLETON

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1918  
Post Publishing Company,  
Opelika, Ala.



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# GRAZING PEANUTS WITH HOGS VERSUS MARKETING A CROP OF PEANUTS\*

By  
GEO. S. TEMPLETON\*

---

## INTRODUCTION

With the rapid increase in the acreage of peanuts in Alabama during the past two years, the question of the best way to market the crop has been a problem for a large number of farmers. The shortage of labor this season and last has made the harvesting of a large acreage, in some sections of the state, very difficult. Occasionally rainy weather during the harvest season damages a large percent of the crop, or the nuts sprout and are unfit for the market. Growing the same crop year after year on the same field is a bad practice from the standpoint of soil fertility and plant disease. The author of this bulletin has several letters from the peanut growing sections of Virginia and North Carolina stating that in those sections large acreages of land have reached the stage where a profitable crop of peanuts cannot be produced, due to the one crop system that removes all of the peanuts and the hay from the soil year after year.

As the peanut crop has grown to be such an important one in Alabama, the Animal Husbandry Department of the Experiment Station planned an experiment to throw as much light as possible on the question as to which is the more profitable,—to sell a crop of peanuts, or graze the crop with hogs?

## OBJECT OF THE EXPERIMENT.

1. The object of this experiment was to determine which is the more profitable,—to market a crop of peanuts or to graze the crop with hogs?
2. To determine the carrying capacity of one acre of peanut pasture.
3. To determine the cumulative effect of both sys-

---

\*Credit is due Mr. V. W. Crawford for the accurate records and the careful supervision of the test for 1917, and to Mr. G. L. Burleson for the similar work for the 1918 test.

tems of marketing the crop on the fertility of the soil.

#### PLAN OF THE EXPERIMENT.

The two tests reported for this experiment were conducted on the farm of T. R. Martin at Union Springs, Alabama. Mr. Martin furnished the hogs, the equipment, and the crops, and the Experiment Station furnished a trained man to personally supervise the tests and keep accurate records. Funds were provided for this test by the State Local Experiment Law.

Mr. Jno. T. Williamson of the Agronomy Department assisted the author in measuring the areas of peanuts and in collecting the data on the cost of harvesting the crop.

In selecting the area for the test each year a uniform area was chosen as to soil character and stand of peanuts.

The small white Spanish peanut was used both years.

On September 4, 1917, one acre of peanuts was measured off and every third row harvested to determine the yield of nuts and hay. The peanuts from the one-third acre were hauled to the barn, stacked in the open, cured, and later thrashed and weighed. The acre was then fenced in and seven high grade Duroc-Jersey and Berkshire pigs were weighed individually and placed on the two-thirds of an acre of peanuts. The similar area harvested yielded at the rate of 39.5 bushels of peanuts per acre. When the crop was consumed by the hogs individual weights were taken.

In the early part of August, 1918, another area of one and one-half acres was measured off for the test. This time one acre was fenced in and on August 23 seven high-grade Duroc-Jersey pigs were weighed individually and turned into the field. The one-half acre of peanuts was harvested as in the previous year. Careful records were made as to the labor required to harvest the chop. The acre yielded 30.2 bushels of peanuts. When the crop was consumed by the hogs individual weights were again obtained.

The following table shows the amount of pork or of peanuts and peanut hay produced on one acre for each of the two year's tests:

TABLE I.—*Showing Amount of Pork, or Peanuts and Peanut Hay Produced on One Acre.*

| Year | No. Hogs | Total initial weight of hogs | Total final weight of hogs | Total pork produced on one acre | Peanuts produced one acre | Peanut hay produced one acre |
|------|----------|------------------------------|----------------------------|---------------------------------|---------------------------|------------------------------|
|      |          | <i>Lbs.</i>                  | <i>Lbs.</i>                | <i>Lbs.</i>                     | <i>Lbs.</i>               | <i>Lbs.</i>                  |
| 1917 | 7        | (2-3 acre)<br>445.5          | (2-3 acre)<br>891          | 668.2                           | 1107                      | 1320                         |
| 1918 | 7        | (1 acre)<br>504.             | (1 acre)<br>920            | 416.                            | 846                       | 732                          |

The hogs used in the two tests were not finished well enough for the market at the close of the test, so they were put in with other hogs on peanut pasture and finished for the market. They were later shipped to the Birmingham Packing Company at Birmingham, Alabama.

#### FINANCIAL STATEMENT.

The hogs used in the test in 1917 were valued at 15 cents per pound when the test was finished, as that was the price on peanut hogs at that time. The local price for peanuts was 6 cents per pound, peanut hay, \$15.00 per ton. Local prices for labor are used in the financial statement. The same values are used in making the 1918 financial statement.

|                                                                                               |  |               |
|-----------------------------------------------------------------------------------------------|--|---------------|
| MARKETING PEANUT CROP VS. GRAZING WITH HOGS, 1917.                                            |  |               |
| 2-3 acre grazed produced at rate of 668.2 lbs. pork per acre, @ 15 cents per lb. -----        |  | \$100.23      |
| 1-3 acre harvested produced at rate of 1107 lbs. peanuts per acre @ 6 cents per lb. -----     |  | \$66.42       |
| 1-3 acre harvested produced at rate of 1320 lbs. peanut hay per acre, @ \$15.00 per ton ----- |  | 9.90          |
|                                                                                               |  | <hr/> \$76.32 |

*Cost of plowing up peanuts, gathering, hauling, stacking and threshing (1 acre):*

|                                                     |               |
|-----------------------------------------------------|---------------|
| 69 man hours @ 50 cents per day -----               | \$3.45        |
| 25 woman hours @ 40 cents per day ---               | 1.00          |
| 6 hours one mule and plow @ \$1.25 per day -----    | .75           |
| 9 hours one two-horse team @ \$2.00 per day -----   | 1.80          |
| 7½ hours one one-horse wagon @ \$1.50 per day ----- | 1.11          |
| 4½ man hours threshing @ 50 cents per day -----     | .22           |
| 39½ bushels threshed @ 10 cents per bu. -----       | 3.95          |
|                                                     | <hr/> \$12.28 |

|                                                 |         |             |
|-------------------------------------------------|---------|-------------|
| Sales from one acre minus cost of harvesting .. | \$64.04 | <hr/> 64.04 |
|-------------------------------------------------|---------|-------------|

|                                                                                             |    |       |
|---------------------------------------------------------------------------------------------|----|-------|
| Profit in favor of grazing crop with hogs (fertilizer removed by crop not considered) ----- | \$ | 36.19 |
|---------------------------------------------------------------------------------------------|----|-------|

## MARKETING PEANUT CROP VS. GRAZING WITH HOGS, 1918.

|                                                                                   |               |
|-----------------------------------------------------------------------------------|---------------|
| One acre grazed produced 416 lbs. pork @ 15 cents per lb. -----                   | \$ 62.40      |
| One-half acre harvested at rate 846 lbs. peanuts per acre @ 6 cents per lb. ----- | \$50.76       |
| One-half acre harvested at rate of 732 lbs. hay @ \$15.00 per ton -----           | 5.49          |
|                                                                                   | <hr/> \$56.25 |

*Cost of harvesting and threshing (1 acre):*

Man hours:

|                                                            |      |
|------------------------------------------------------------|------|
| Plowing up peanuts, 5½ hrs. @ 50 cents per day -----       | .27  |
| Gathering peanuts 22 hrs. @ 50 cents per day -----         | 1.10 |
| Hauling peanuts, 10 hrs. @ 50 cents per day -----          | .50  |
| Fixing poles for stacking, 2 hrs. @ 50 cents per day ----- | .10  |
| Stacking, 10 hrs. @ 50 cents per day ----                  | .50  |
| Threshing, 6 hrs. @ 50 cents per day --                    | .30  |

Horse hours:

|                                                    |               |
|----------------------------------------------------|---------------|
| Plowing up peanuts, 5½ hrs. @ \$1.25 per day ----- | .68           |
| Hauling (team) 5 hrs. @ \$2.00 per day --          | 1.00          |
| 30.2 bushels threshed @ 10 cents per bu. 3.02      |               |
|                                                    | <hr/> \$ 7.47 |

Sales from one acre, minus cost of harvesting -- \$48.78 

---

\$ 48.78Profit in favor of grazing a crop of peanuts with hogs,  
(fertilizer removed by crop not considered) ---- \$ 13.62

From the above financial statements it is seen that in 1917 *grazing the acre of peanuts returned \$36.19 more than was received for the crop of peanuts and peanut hay.* In other words, the hogs paid their owner the market price for the crop, harvested the crop, and returned a net profit of \$36.19 per acre more than the crop would have sold for on the market.

The financial statement for the 1918 test shows that there was a *balance of \$13.62 per acre in favor of grazing the crop with hogs.*

The above statements do not give all of the results that are to be derived from the two systems of marketing the crop.

A permanent system of agriculture is an ideal to strive for. The removal of all of the plant food from the soil year after year, by selling the entire crop, can lead to but one result, and that is depletion of the soil.

In marketing the crop by grazing or selling it is only fair in making a financial statement to debit or credit the field on which the crop was raised with the amount



of plant food removed or added to the soil as a result of the two systems being tested by the experiment.

It is planned to make more tests in the future on this question, and the cumulative effect of both systems on the productive quality of the soil will be reported later.

#### AMOUNT OF PEANUTS REQUIRED TO PRODUCE ONE POUND OF PORK.

One of the striking results in both years' tests is the small amount of peanuts required to produce one pound of pork. The 1917 crop yielded 1107 pounds (39.5 bu.) of peanuts to the acre and produced 668.2 pounds of pork. One pound of pork was produced on 1.65 pounds of peanuts plus forage. The 1918 crop yielded 846 pounds (30.2 bu.) of peanuts to the acre and produced 416 pounds of pork. One pound of pork was produced on 2.03 pounds of peanuts plus forage. The average amount of peanuts for the two tests to produce one pound of pork is 1.84 pounds. As the entire crop was grazed by the hogs the peanuts were a supplement to the forage crops, as the hogs ate a considerable amount of peanut vine, Florida pursley, and weeds.

In Bulletin No. 93 published by this Station, Prof. J. F. Duggar states as the result of an experiment conducted by him in 1897 that: "When fed to pigs in pens only 2.8 pounds of unhulled Spanish peanuts were required to produce each pound of increase in live weight."

#### CARRYING CAPACITY OF ONE ACRE OF PEANUT PASTURE.

The length of time one acre of peanuts will carry a certain number of hogs will depend on the size of the hogs and upon the yield of the crop. The following table shows the average initial and average final weights of the hogs and the yield of peanuts in the two tests:

TABLE II.—*Number of Days One Acre of Peanuts Carried Seven Pigs.*

| Year | Yield of peanuts to acre | Average initial weight of each pig | Average final weight of each pig | Average daily gain | No. of days 1 acre carried seven pigs |
|------|--------------------------|------------------------------------|----------------------------------|--------------------|---------------------------------------|
|      | <i>Bu.</i>               | <i>Lbs.</i>                        | <i>Lbs.</i>                      | <i>Lbs.</i>        | <i>Days</i>                           |
| 1917 | 39.5                     | 63.5                               | 128.7                            | 1.67               | 57                                    |
| 1918 | 30.2                     | 72.                                | 131.4                            | 1.60               | 37                                    |

With the information contained in the above table it is possible for the farmer to determine what acreage of peanut pasture will be required to accommodate a definite number of shoats of the above weights.

#### SUMMARY STATEMENTS.

1. An acre of peanuts in the first test (1917), yielding 39.5 bushels, returned a net profit of \$36.19 in favor of grazing the area with hogs over selling the crop on the market, when pork was 15 cents a pound, peanuts 6 cents a pound, and peanut hay \$15.00 per ton.

2. In the second test (1918) the hogs gathered an acre of peanuts yielding 30.2 bushels and paid their owner the market price for the nuts and hay, saved the labor of harvesting, and returned him a net profit of \$13.62 above what the crop would have netted him if it had been sold on the market.

3. When the hogs grazed the entire crop of peanuts yielding 39.5 bushels to the acre, the acre produced 668.2 pounds of pork.

4. A crop of 30.2 bushels of peanuts to the acre produced 416 pounds of pork.

5. In the two tests reported in this bulletin 1.65 pounds of peanuts in the first tests (1917, and 2.03 pounds of peanuts in the second test (1918) produced one pound of pork: or, an average of 1.84 pounds of peanuts, plus the forage furnished by the crop of peanuts and other vegetation, produced one pound of pork.

6. An acre of peanuts yielding 39.5 bushels furnished grazing for seven pigs weighing 63.5 pounds (average weight at beginning of test) for 57 days.

7. An acre of peanuts yielding 30.2 bushels furnished grazing for seven pigs weighing 72 pounds (average initial weight) for 37 days.

Thirty-First Annual Report

OF THE

Agricultural Experiment  
Station

OF THE

Alabama Polytechnic Institute

Auburn, Alabama

January, 1919



Thirty-First Annual Report

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Auburn, Alabama

January, 1919





ALABAMA POLYTECHNIC INSTITUTE

Auburn, Ala., Jan. 24, 1919.

Governor Thomas E. Kilby,  
Executive Department,  
Montgomery, Ala.

Sir:

I have the honor herewith to transmit to you the Thirty-first Annual Report of the Agricultural Experiment Station of the Alabama Polytechnic Institute.

This report is made in accordance with the Act of Congress approved March 2, 1887, establishing agricultural experiment stations, and the Act of Congress approved March 16, 1906, known as the Adams Act.

Respectfully,  
CHAS. C. THACH,  
President.



Auburn, Ala., Jan. 23, 1919.

Dr. C. C. Thach, President,  
Alabama Polytechnic Institute,  
Auburn, Ala.

Sir:

I herewith submit the Thirty-First Annual Report of the Experiment Station of the Alabama Polytechnic Institute for the fiscal year ending June 30, 1918.

It contains the detailed report of the Director, the Agriculturist, the Treasurer, the Chemist, the Veterinarian, the Botanist, the Horticulturist, the Entomologist, the Plant Pathologist, and the Animal Husbandman, for the year ending December 31, 1918.

Respectfully submitted,  
J. F. DUGGAR,  
Director, Experiment Station.





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J. C. C. Price, Associate.  
L. A. Hawkins, Assistant.

### ENTOMOLOGY:

W. E. Hinds, Entomologist.  
F. L. Thomas, Assistant.  
J. M. Robinson, Assistant.

### ANIMAL HUSBANDRY:

G. S. Templeton, Animal  
Husbandman.  
F. O. Montague, Assistant.  
E. Gibbens, Assistant.  
G. L. Burleson, Assistant.  
F. W. Burns, Assistant.

### EDITOR:

Leslie L. Gilbert.

# REPORT OF HATCH AND ADAMS FUNDS FOR 1917-1918

## Receipts.

|                                     | Hatch       | Adams       |
|-------------------------------------|-------------|-------------|
| To amount from U. S. Treasury (Net) | \$15,000.00 | \$15,000.00 |

## Disbursements

|                                       |             |             |
|---------------------------------------|-------------|-------------|
| By Salaries                           | \$ 7,386.72 | \$ 8,742.15 |
| By Labor                              | 1,977.85    | 1,522.02    |
| By Publications                       | 2,181.46    |             |
| By Postage and Stationery             | 338.58      | 125.24      |
| By Freight and Express                | 222.68      | 184.38      |
| By Heat, Light, Water and Power       | 433.24      | 363.74      |
| By Chemicals and Laboratory Supplies  | 9.93        | 1,452.48    |
| By Seeds, Plants and Sundry Supplies  | 785.78      | 257.19      |
| By Fertilizers                        | 591.78      | 50.00       |
| By Feeding Stuffs                     | 89.70       | 532.40      |
| By Library                            | 255.45      | 135.62      |
| By Tools, Machinery and Appliances    | 319.12      | 27.99       |
| By Furniture and Fixtures             | 54.50       | 207.84      |
| By Scientific Apparatus and Specimens | 4.87        | 641.20      |
| By Live Stock                         | 18.62       |             |
| By Traveling Expenses                 | 98.43       | 644.57      |
| By Contingent Expenses                | 20.00       |             |
| By Buildings and Land                 | 211.29      | 113.18      |

|       |             |             |
|-------|-------------|-------------|
| Total | \$15,000.00 | \$15,000.00 |
|-------|-------------|-------------|

Respectfully,

(Signed): M. A. GLENN,

State of Alabama:

Treasurer.

Lee County.

Personally appeared before me, B. L. Shi, a Notary Public in and for said county, M. A. Glenn, known to me as Treasurer of the Alabama Polytechnic Institute, who, being duly sworn, deposes and says the above foregoing account is true and correct. Witness my hand this 17th day of January, 1919.

B. L. SHI,

Notary Public, Lee County.

This is to certify that I have compared the account with the ledger account of the Treasurer, and this is a correct transcript of the same.

CHAS. C. THACHE,

President Alabama Polytechnic Institute.



## REPORT OF DIRECTOR

J. F. DUGGAR

Auburn, Ala., Jan. 22, 1919.

Dr. C. C. Thach, President,  
Alabama Polytechnic Institute,  
Auburn, Ala.

Sir:

I respectfully submit the following report for the past year of the work under my charge as Director of the Alabama Experiment Station:

### PUBLICATIONS

The publications of the Alabama Experiment Station for the fiscal year ending June 30, 1918, consist of the annual report, eight bulletins, two circulars, and five press bulletins, making a total of sixteen publications. Below I give their titles and authors:

Bulletin No. 197: "Harvesting and Storing Sweet Potatoes;" by the Associate Horticulturist.

Bulletin No. 198: "Velvet Beans Compared with Cotton Seed Meal For Fattening Steers, etc.;" by the Animal Husbandman (From the Local Experiment Fund.)

Bulletin No. 199: "Report on Freeze Injury to Citrus Trees for 1916 and 1917, with Notes on Orange Culture in South Alabama;" by O. F. E. Winberg, Horticulturist and Field Agent. (From the Local Experiment Fund.)

Bulletin No. 200: "Tests of Varieties of Corn at Auburn;" by Agriculturist.

Bulletin No. 201: "The Development of Soluble Manganese in Acid Soils as Influenced by Certain Nitrogenous Fertilizers;" by Associate Agronomist.

Bulletin No. 202: "Growing Soy Beans in Alabama;" by the Agriculturist.

Bulletin No. 203: "Soy Beans in Alabama;" by the Agriculturist.

Bulletin No. 204: "The Destruction of Vanillin in the Soil by the Action of Soil Bacteria;" by the Botanist.

Circular No. 37: "Sweet Potato Root Borer;" by the Entomologist. (From the Local Experiment Fund.)



Circular No. 38: "Annual Report of the Director of the Experiment Station on Work Done Under the Local Experiment Law in 1917." (From the Local Experiment Fund.)

Press Bulletin No. 90: "How to Save Alabama's Corn Crop;" by the Entomologist.

Press Bulletin No. 91: "Tests of Varieties of Corn in 1917;" by the Agriculturist.

Press Bulletin No. 92: "Tests of Varieties of Cotton in 1917;" by the Agriculturist.

Press Bulletin No. 93: "Corn Insect Control Through Seed Selection and Trap Planting;" by the Entomologist. (From the Local Experiment Fund.)

Press Bulletin No. 94: "Fumigation Treatment to Save Corn and Peas;" by the Entomologist.

## ADAPTING EXPERIMENT STATION WORK TO NATIONAL NEEDS

After America entered the war heads of departments of the Experiment Station were requested to give preference to those projects having an immediate bearing on the increase of the nation's food supplies. An examination of the projects then in hand showed that so many of them already had this direct application to food production problems that relatively little change in the entire plan of work was made necessary by the national emergency.

## MAIN LINES OF WORK IN VARIOUS DEPARTMENTS

The attached reports of heads of departments afford statements of the lines of work in progress in the Alabama Experiment Station. It is in place here to allude briefly to only a few of these, and only to results at the main Station, reserving for a later report a statement regarding the experiments conducted under the Local Experiment Law in the various counties of the state.

*Plant Breeding*—On the Experiment Station farm at Auburn during the past year, as for a number of years, a large amount of attention has been given to the breeding up of new strains or varieties of cotton, corn, and oats. In addition the breeding of wheat, peanuts, and some other plants is in progress.

*Cotton*—So favorably have the varieties bred up at Auburn proved their worth in farmers' hands that where they are being tested by farmers with reference to their local adaptation the seed have been in great demand in the immediate neighborhood. This has been especially true of certain strains of Cook cotton, several of which have shown notable superiority to standard varieties in yield of lint per acre, and in percentage of lint.

As an example of the estimate placed on some of these bred-up strains by farmers is a statement from a farmer in Dallas County, who after producing the past year on 5 acres 4860 pounds of seed cotton from one of these bred-up strains of Cook cotton seed, reported that his crop made an out-turn of 40.8 per cent of lint and yielded 25 per cent more lint per acre than the remainder of his crop planted in an ordinary variety.

Another strain of Cook evolved here in this process of plant breeding has developed the valuable quality of wilt resistance, together with high productiveness.

*Oats*—A cross or hybrid made at Auburn between two standard varieties of oats has thus far shown great promise in withstanding better than its Red Rust proof parent the severe freezes of the last two winters.

In the long continued experiment to determine the effects as regards resistance to winter killing of sowing seed oats of which the ancestors for a number of generations had become accustomed to fall sowing, as compared with the planting at the same time in the fall of seed oats most of whose progenitors had been sown in the spring, we have now reached conclusive proof of the superior hardiness of the fall sown strain. The practical point of this lies in the fact that it emphasizes the superiority for seed purposes of home grown oats of known cultural history as compared with Texas or Oklahoma oats descended from a strain sown there after Christmas.

*Soy Beans*—The results of experiments made through a number of years with soy beans have recently been published, and the two bulletins on this subject constitute a guide for the growing of this crop so promising of development, especially in central and north Alabama, both as a feed for hogs and as one of the plans promising to assist in the further development of the oil industry of the state.

*Fertilizer Tests*—The work with fertilizers on the Experiment Station farm has been largely directed to determining the relative values of peanut meal and velvet bean meal in comparison with the fertilizing value of cotton seed meal and nitrate of soda. The results of the last year's tests will be made known at once through the press, so as to help farmers in their purchases of fertilizer in the present winter and approaching spring.

*Investigation of soils*—Painstaking investigations of the soil expert have indicated the great decrease in crop yield due to soil acidity, and have indicated that the application of various fertilizers has a notable effect in increasing this acidity and therefore in increasing the need for the use of lime.

*Sweet Potato Storage*—Both the departments of horticulture and botany are pursuing investigations to reduce the losses of sweet potatoes during winter storage.

*Plant Diseases*—The Plant Pathologist in his study of the life history of the organism causing the disease citrus canker, which at one time threatened to destroy the entire Satsuma orange industry of the southern part of the state, has brought to light important facts which are being utilized in the successful warfare now being waged for the extermination of this disease.

*Insect Pests*—The Entomologist has brought to play, in reducing the insect injury to stored corn, the results of his successful study of the life history of the weevil responsible for this damage. The methods of reducing the injury to corn by this weevil found most practicable are the planting of seed corn from ears having tips well covered and protected by tight fitting shucks, and the early planting near the cribs, (where the weevils spend the winter), of small patches of early corn to serve as traps for the weevil. By the feeding of this early corn before it is thoroughly matured most of the weevils are destroyed and their propagation on the main crop prevented.

*Feeding Experiments with Hogs*—The Animal Husbandry department has obtained important results in showing the effects of peanuts, peanut meal and other feeds on the quality of pork and lard. The feeding of velvet beans variously prepared is being continued, and chemical work has in recent months

been begun of the entire velvet bean plant, including an examination to determine whether it contains any toxic substances that may be responsible for the unfavorable results sometimes reported with pregnant sows.

#### CHANGES IN STAFF

During the year covered changes occurred in the headship of two departments. The Agricultural Engineer, Professor R. U. Blasingame, resigned to accept a corresponding position with the Agricultural College of Pennsylvania; and Dr. Wright A. Gardner was appointed Botanist in September, 1917, in succession to Dr. W. J. Robbins, who resigned to engage in a business enterprise. There has been a number of changes among assistants.

For further details the reports of the several heads of departments should be consulted.

Respectfully submitted,  
J. F. DUGGAR,  
Director.

REPORT OF AGRICULTURIST  
(Work under Hatch and Adams Funds)

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E. F. CAUTHEN

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*Cotton*—Cotton breeding received a great deal of attention along the lines pursued in previous years. Cleveland and Cook varieties and also a hybrid (King and Triumph) were grown in plant-to-row tests and considerable data were taken on type of plants, size of bolls, length of fiber, earliness, resistance to disease, etc., for use in the study of correlation. While making a careful study of these varieties, as a plant breeding project, some very desirable strains of Cook and Cleveland have been isolated, and their seed placed among farmers for multiplication.

Five cotton hybrids, including Cook Unknown, and Cook Trice were planted in isolated places and studied. A hybrid of a short staple variety crossed on Yuma (a long staple Egyptian cotton) was studied with a view to determining the dominant and recessive characters.

The variety tests included a comparison of 22 leading short staple varieties in regular plots, 17 less well known varieties for observation, and 9 varieties in a long staple test. The experiment comparing light and heavy seed was continued. A test of the effects of topping at different ages on earliness and yield was made; also the effects of thinning early and late, planting the seed on a bed, on a level, and in a water furrow.

*Corn*—Considerable attention was given by Mr. Tisdale to the project in corn breeding. The work of correlating the different ear characters is being continued with two prolific varieties; Experiment Station Yellow, a yellow flint variety, and Whatley, a white dent weevil-resistant variety. The characters of the ear and shuck that fit it for weevil resistance are being correlated with yield and other characters. The ear-to-row method is used on the two varieties in testing the characters that give a high correlation and in selecting for strains of corn best suited to Alabama conditions.

Eighteen varieties of corn were tested in plots for compara-



tive yield and 12 less well known varieties were grown in rows for observation. A test of varieties for late planting included Goliad, Dwarf Mexican June, Lowman Yellow and Experiment Station Yellow. The test of the Williamson method of planting corn was continued.

*Oats*—The regular fall planted variety test of oats included most of the promising southern varieties. The severe freeze of the winter of 1917 and 1918 showed that Culberson was the most resistant to winter killing of the "rust proof" group. Among the hybrids No. 651, a cross made at Auburn of Culberson on Red Rust Proof withstood the freezes of both preceding winters.

The Red Rust Proof and Fulghum varieties were planted in plant-to-row tests for study and from them some promising strains have been isolated. Forty to fifty bushels of pedigreed seed have been placed with selected farmers for further testing and multiplication. When bearded and beardless kernels are separated from the same head and planted, their progeny show on the same plant both bearded and beardless kernels in about the same proportion as on the parent plant.

The test of fall versus spring planting of oats continued to show from 20 to 40 per cent increase in yield in favor of the fall planting. In the spring planted variety tests Burl, Fulghum and Dixie produced the largest yields of grain. In seeding oats after cotton on sandy upland the plowing of the land as a preparation has not increased the yield.

*Wheat*—In the regular variety tests of wheat were included both those varieties that have been grown here many years and those that have not yet become well established. Among those that are well established is the Alabama Blue Stem, a local variety that deserves special mention because it has been found to do well in many parts of the state. The breeding of the Alabama Blue Stem by the plant-to-row method has given several strains, some of which seem to be more resistant to leaf rust than others. The experiment in rate of seeding wheat seemed to bear out the common practice of seeding about 60 pounds per acre. February planting of wheat gave low yields.

*Barley*—The work with barley included a variety test plant-

ed in the fall and one planted in February. In the February planting the hooded and beardless varieties yielded well and these seem to offer special promise for early spring planted grain and feed.

*Rye*—The principal work with rye for 1918 was a regular variety test, which showed that a native variety from Tuscaloosa county was equal to Abruzzi in yield and seemed more resistant to anthracnose.

*Soy Beans*—The experiments with soy beans included rate of seeding both for hay and for seed; regular variety tests for both seed and for hay; a fertilizer test, which seemed to indicate very little advantage from any particular kind of fertilizer; and harvesting and thrashing of soy beans. A test of soy beans, cowpeas, corn, and velvet beans was made to get the comparative yield of grain of each crop.

*Commercial Fertilizer*—The experiments testing the time when nitrate of soda should be applied to corn and cotton to secure the greatest benefits were repeated. Peanut meal, velvet bean meal, and cotton seed meal were compared with nitrate of soda as a source of nitrogen for corn and cotton, and gave results strongly favorable to nitrate of soda. The comparison of acid phosphate with fine ground rock phosphate under oats and soy beans, corn and cotton was continued. Potash from different sources (cement potash, kelp ash, kainit, sulphate, and Nebraska potash) was tested under cotton to compare their availability.

In addition to the above mentioned experiments, the following were conducted on the Alabama Experiment Station farm in 1918:

Grasses, test of species and varieties.

Hog crops, relative yields from chufas, peanuts, soy beans, etc.

Kudzu.

Phosphates, raw versus acid.

Peanuts, variety tests, fertilizer tests.

Rotation experiments.

Rate of seeding peanuts.

Residual effect of different crops on soil fertility.

Sorghum, tests of varieties for forage and for syrup.

Subsoiling.

Sudan grass for hay and its mixtures with cowpeas.

Sugar cane, Japanese as a forage crop.

Tangier peas for seed.

Velvet beans, varieties for seed and from different sources.

Vetches, varieties.

Vetches, best mixtures.

Respectfully submitted,

E. F. CAUTHEN,

Agriculturist.

## REPORT OF AGRONOMIST

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M. J. FUNCHESS

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Auburn, Ala., Jan. 10, 1919.

Director J. F. Duggar,  
Auburn, Ala.

Sir:

I beg to submit the following brief report of the work done during the past year.

A study of the lasting effect of certain organic toxins was continued, with results very similar to those obtained in previous years. There is no indication of lasting toxicity of organic toxins applied to soils. Immediately after their application, a marked toxicity may be caused by certain compounds. In time, this toxicity disappears and normal plant growth is sustained.

Work on the development of soluble manganese in acid soils was continued, using ten soils of widely differing characteristics. The application of dried blood produced more soluble manganese in each of the acid soils; and small amounts of aluminum were also found in a few of these. Recent work seems to indicate, however, that actual acidity rather than soluble manganese may be responsible for a part of the toxicity found in soils fertilized with dried blood.

Manganese nitrate added to the soils used in this study proved to be toxic when used at the rate of 100 parts of manganese per million parts of soil, and at all higher rates. Plants were killed in most soils when the rate was 300 parts per million. In limestone soils well supplied with calcium carbonate, manganese used at the above rates caused little or no injury.

By means of experiments now under way, it is hoped that the relative importance of acidity and of salts in solution as the cause of toxicity, may be established.

Respectfully submitted,

M. J. FUNCHESS,

Agonomist.

## REPORT OF BOTANIST

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WRIGHT A. GARDNER

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Auburn, Ala., Jan. 18, 1919.

Director J. F. Duggar,  
Alabama Experiment Station,  
Auburn, Ala.

Sir:

I beg leave to submit the following report of experimental work conducted by the Department of Botany during the past year.

Adams Fund Projects.

(1) Soil Toxin Project. Various claims have been made with reference to the presence of poisonous substances in soils. Some claim that poisonous substances are excreted by the roots; others claim that they are products of the decomposition of plant and animal tissue. The majority of those interested in soil fertility investigations admit the presence of these poisonous substances whether they consider them important or not. The workers in the Bureau of Soils in Washington have separated from soils several substances poisonous to crop plants, such as wheat, corn and peas. The workers in this laboratory have been seeking agencies and conditions for the destruction of these injurious substances. W. J. Robbins, in Bulletin 204, *The Destruction of Vanillin in the Soil by the Action of Bacteria*, June, 1918, shows that certain bacteria decompose vanillin and points out several conditions favorable to its decomposition. Two lines of investigation are now being carried on. One deals with the relation of oxygen and water to the decomposition of vanillin in the soils. Results so far obtained indicate that under soil conditions an inadequate water supply is more frequently the limiting factor. The other investigation deals with the decomposition of toxins by soil bacteria. Results obtained indicate that many soils from Alabama and elsewhere, though not all, contain organisms which decompose cinnamic acid, resorcin, and vanillin, that some soils contain organisms which decompose guanidine hydrochloride, piperidine, and cumarin,



and that a few soils contain organisms which decompose benzidine, caffein, pyridine and quinoline. No soils examined contain organisms which decompose hydrochinone saicylic aldehyde, or oxalic acid.

(2) Sweet Potato Project. In view of the loss of sweet potatoes during the winter of 1917-18 on account of chilling it seemed desirable to make a study of the changes undergone by sweet potatoes during storage under various controlled conditions. Investigations of the changes in cell walls and cell contents of sweet potatoes stored under various conditions and subjected to change of temperature are already under way. An attempt will be made to show which processes and conditions are responsible for the injury due to chilling and what agencies actually cause the injury.

#### Hatch Fund Projects.

No projects have been definitely outlined under the Hatch Fund. Some work has been done on each of the following:

(1) The effect of certain factors in the digestion of cellulose by *Penicillium* species.

(2) Manganese poisoning of plants.

The experiment station projects in the Botany Department are:

(1) Soil toxin project, Adams Fund.

(2) Sweet Potato project, Adams Fund.

(3) Miscellaneous botanical investigations, Hatch Fund.

Respectfully submitted,

WRIGHT A. GARDNER,

Botanist.

## REPORT OF PLANT PATHOLOGIST

G. L. PELTIER

Auburn, Ala., Dec. 16, 1918.

Prof. J. F. Duggar, Director,  
Agricultural Experiment Station.  
Auburn, Ala.

Sir:

I am herewith submitting a brief statement of the work now in progress in the Department of Plant Pathology.

(1) Under the Adams fund the citrus-canker project has been continued, the results obtained being embodied in the following papers:

Susceptibility and resistance to citrus canker of the wild relatives, citrus fruits, and hybrids of the genus citrus. (Preliminary paper) Journal of Agricultural Research XIV, No. 9, 337-357 (Aug.) 1918, pls. 50-53.

Overwintering of the citrus canker organisms in the outer bark tissues of the hardy citrus hybrids. (with D. C. Neal.) Journal of Agricultural Research XIV, No. 11, 523-524. (Sept.) 1918, pl. 58.

A convenient heating and sterilizing outfit for a field laboratory. (With D. C. Neal.) Phytopathology VIII, No. 8, 436-438. (Aug.) 1918, 2 figs.

Susceptibility and resistance to citrus canker of the wild relatives, citrus fruits, and hybrids, of the genus citrus. (Progress report.) In preparation.

Several promising fruits and plants suitable for stock which may be successfully grown in South Alabama have been found to be quite resistant to citrus canker. Observations during the winter of 1917-1918 have shown that the canker organism can, after gaining entrance into the bark tissues, remain dormant (6 months) through the winter and break out in a virulent stage when conditions are favorable for its development.

Some progress has been made on a method for isolating the canker organism from the soil, while the same may be said of a number of experiments associated with the life-history of the organism.

On November 11, 1918, the writer was granted a four months leave, to study the influence of temperature and humidity on the development of the citrus canker organism and the disease caused by it, in the botanical laboratories and green houses of the University of Illinois.

(2) Some of the Local Experiment Fund has been used to maintain the field laboratory at Loxley, Alabama. Besides a study of citrus canker, observations have been made on the plant diseases peculiar to South Alabama and the farmer advised in preventive and control measures.

No definite projects have been started but the work under the Local Experiment Fund this past year has been confined to observations of a number of troublesome plant diseases, some of which are new or little known in Alabama.

Respectfully submitted,

GEORGE L. PELTIER,

Plant Pathologist.

## REPORT OF HORTICULTURIST

G. C. STARCHER

Auburn, Ala., Jan. 15, 1919.

Prof. J. F. Duggar,  
Director of Experiment Station,  
Auburn, Ala.

Sir:

In response to your request, I herewith submit a report on the progress of the work in this Department.

Pecans—We have continued our notes on the variety pecan orchard.

Peaches—We continued our notes on varieties of peaches. Some new varieties originated here are being propagated. We also continued our notes on spraying of peaches with different materials.

Pears—We have continued our notes on varieties of pears, with especial reference to susceptibility to blight. We added to the variety planting for this purpose.

Strawberries—We made a variety planting of twenty-nine varieties.

Raspberries—We made a variety planting of five red raspberries and five black cap raspberries.

Blackberries—We planted five varieties of blackberries, the Lucretia dewberry and the Loganberry.

Sweet Potatoes—We have started a new series of sweet potato storage experiments to determine the influence of time of digging, i. e., before and after the vines were frosted, and the influence of temperature and ventilation on the keeping of the potatoes. For carrying out these experiments we have remodeled the storage house formerly used. We now have three rooms, one large room heated by a coal stove and one small room heated by an oil stove. Neither of these rooms has a dead air space in the floor or ceiling. A third room, heated by an oil stove, has a dead air space in the walls, ceiling and floor. Careful thermo-hygrograph records are being kept in all the rooms.

The experiments in the house are being correlated with

storage experiments in hills.

Tomatoes—Variety experiments were started to note comparative wilt resistance of various varieties of tomatoes.

Melons—Our notes were continued on the yield, quality and keeping qualities of watermelons and muskmelons.

It will be practically impossible to do any new work with horticultural plants because we have little or no soil uniform enough for either variety tests or fertilizer work. Much of the soil which we have is so infected with nematode and disease, due to long use, that many plants cannot be grown at all.

The Department can do no work of importance until our funds are increased and suitable land secured.

Respectfully yours.

G. C. STARCHER,  
Horticulturist.



## REPORT OF ENTOMOLOGIST

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W. E. HINDS

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Auburn, Ala., Dec. 28, 1918.

Prof. J. F. Duggar,  
Auburn, Ala.

Sir:

I submit below a report of the entomological work done during the past year under Adams and Hatch Funds.

Adams Fund Projects—1, Rice Weevil.

This project has been continued principally in the field. The practicability of utilizing "trap plots" for concentrating the first generation of *Calandra* and other species so that they may be removed while still in the grain and disposed of in such a manner as to prevent their spread to later maturing corn has been further tested and with satisfactory results. The field study of weevil resistance as shown by various varieties of corn has been continued. Whatley's Prolific still continues to lead in the desired combination of high yield and soundness of grain due to exceptionally good shuck covering. Owing to the great increase in yield in the crop of 1917 and also to the exceptionally cold winter the insect damage to the stored crop of that season was very much less than average through the State.

2. Arsenate of Lead—Work in this project was resumed using cotton and the boll weevil as experimental subjects. Some eighteen plots located mainly in the southeastern corner of the State where the heaviest infestation was expected, were dusted at various stages of the cotton and for a varying number of applications. The outdoor work was correlated with indoor cage experiments and chemical analyses of all materials used are being made by the Research Chemist. The field which showed the largest increase in yield, apparently due to the treatment, is being given a very close, detailed study. As a whole the results do not yet justify the recommendation of Arsenate of Lead or any other poisons dusting for boll weevil control.

3. Fumigation—Under this project we have entered a new phase of the work in the treatment of soils for the destruction

of various insects, such as white grubs, termites, woolly aphis, etc., and also for nematode worm control. The results thus far have shown that Sodium Cyanide may be used in solution at the rate of one (1) oz. in eight (8) gallons of water and at this strength it did not injure the foliage of any one of the numerous plants tested. When soil was saturated with this solution at such a rate that one (1) oz. of the Sodium Cyanide was applied to 10 to 12.5 square feet of area we obtained very satisfactory results in the practically complete control of white grubs, earthworms, termites, sow bugs and nematodes. It appears now that we have found a very fairly effective, economical and practicable method of fighting some of the soil infesting animals which have been very troublesome and almost impossible of control in the past. This is an extremely important field of study and will be continued. Even at present high prices for chemicals, the cost of treatment will not be over about \$70.00 per acre. Furthermore, the work thus far has shown an extremely gratifying stimulation in the growth of all plants tested on the cyanide treated areas, which indicates that the treatment has a very important fertilizing, as well as a pest controlling value.

In the fumigation of Satsuma orange trees for the control of scale insects, white fly, etc., we have secured very satisfactory results so far as the control of these pests is concerned, but the cost of tents, chemicals, etc., has been so high under war conditions and the danger of spreading citrus canker is so great in some sections that this treatment is not likely to supersede spraying for some time yet.

Carbon disulphid fumigation for the destruction of the sweet potato root borer has not given satisfactory results when used in the sweet potato storage banks. It fails to kill all stages of the insect and evidently increases the rotting of the potatoes.

#### Other Projects:

Inspection work, carried on by the U. S. Bureau of Entomology agents in co-operation with this Department and with the Alabama State Board of Horticulture, has failed to reveal the presence of the sweet potato root borer at any other locality in Alabama than around Grand Bay in Mobile County. A determined effort is being made to exterminate this weevil this

season. Fortunately only seven or eight premises have been found infested and in all cases destruction of the crop has been secured under the tactful supervision of Dr. O. F. E. Winberg who has kindly served as field director of this work.

Respectfully submitted,

W. E. HINDS,

Entomologist.

## REPORT OF ANIMAL HUSBANDMAN

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GEO. S. TEMPLETON

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Auburn, Ala., Jan. 14, 1919.

Prof. J. F. Duggar, Director,  
Alabama Experiment Station,  
Auburn, Ala.

Sir:

I respectfully submit the following report of the experimental work conducted by the Animal Husbandry Department during the past fiscal year. The experiments conducted at Auburn were supported by the Hatch and Adams funds appropriated by Congress. The experiments conducted in Marengo, Mobile and Bullock counties were supported by the State appropriation provided by the Local Experiment Law.

A study of the influence of some southern feeds upon the properties (melting point, keeping qualities, iodine value, and color) of lards was conducted in co-operation with the Department of Chemistry. Six lots of hogs, eight hogs to the lot, were fed the following ration:

Lot 1—Corn, 8 parts, tankage, 1 part.

Lot 2—Corn, 1 part, peanut meal, 1 part.

Lot 3—Corn, 2 parts, peanut meal, 1 part.

Lot 4—Corn, 3 parts, peanut meal, 1 part.

Lot 5—Corn, 4 parts, velvet bean and pod meal, 4 parts, tankage, 1 part.

Lot 6—Corn,  $1\frac{1}{2}$  parts, velvet bean and pod meal,  $1\frac{1}{2}$  parts, peanut meal, 1 part.

The ration for Lot 5 proved to be unpalatable, and after it was continued nineteen days it was thought impracticable to continue the ration so the feed for this lot was changed to corn, 8 parts, and peanut meal, 1 part. The six lots were fed for a period of 104 days, when they were sufficiently finished for marketing. The hogs were marketed at the Birmingham Packing Company in Birmingham, Alabama. Cold storage notes were made on the carcasses, and samples of kidney fat from each individual in all the lots were given to the Chemistry Department for laboratory work. The Chem-

istry Department will make a report on the analyses.

The carcasses in Lot 1, corn and tankage, were entirely satisfactory to the packer. They were nicely finished and of excellent quality. Lots 2, 3, and 4, receiving varying amounts of peanut meal with corn, were classified by the packer as medium soft, and docked on this basis. The ration containing velvet bean and pod meal did not prove to be as palatable as the rations in Lots 1, 2, 3, and 4; consequently Lots 5 and 6 ate a much smaller amount of feed and made relatively smaller gains, and were not as nicely finished as those in the first four lots. The corn and peanut meal rations were very palatable and the hogs made uniformly good gains on these mixtures.

The average melting points for the lots were as follows:

Lot 1—44.15 degrees C.

Lot 2—40.35 degrees C.

Lot 3—42.2 degrees C.

Lot 4—40.57 degrees C.

Lot 6—42.5 degrees C.

During the year a test was started to determine the best and most economical method of preparing velvet beans in the pod as feed for dairy cattle. Three lots of four cows each were fed as follows:

Lot 1—Velvet beans in the pod (ground.)

Lot 2—Velvet beans in the pod (soaked.)

Lot 3—Velvet beans in the pod (dry.)

This work has not yet continued long enough for definite conclusions to be drawn.

Respectfully submitted,

GEO. S. TEMPLETON,

Animal Husbandman.



## REPORT OF VETERINARIAN

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C. A. CARY

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Auburn, Ala., Jan. 9, 1919.

Director J. F. Duggar,  
Auburn, Ala.

Sir:

During 1918 the following work was done.

(1) An attempt was made to ascertain the toxic effects of red buckeye (*Aesculus pavia*) when ingested by pigs.

One pig was given one half ounce of leaves, gathered in the fall, twice daily in feed for five days, then one ounce of buckeye leaves twice daily for five days and then given one and one half ounces twice daily for five days.

Another pig was given the ground bark and roots, the same amount, same dosage and for the same periods of five days each. The feed given each pig was two parts of velvet bean meal and one part of shorts.

Each one of these two pigs in 15 days gained eleven pounds in weight; the daily temperature of each was normal. Blood counts, made before and after the tests were finished, gave no distinct changes in red blood cells or in leucocytes. These two pigs remained in good health and maintained a good appetite.

A control pig was fed the same ration of velvet bean meal and shorts and gained ten pounds in the 15 days. The condition of this pig was practically the same as the two pigs eating the buckeye leaves and bark roots.

One pig was given freshly chopped buckeye nuts, gathered in fall, in green condition, in same doses twice daily in velvet bean meal and shorts for the same periods. The pig ate very little of the feed containing the nuts and lost four pounds during the fifteen days. Toward the end of the test this pig was dull, sluggish, inactive and had an unsteady gait. (This test should have been continued or repeated on one or more pigs and some means obtained to cover up the taste of the chopped nuts.) The result is doubtful but suggestive of some toxic effects.

In the Spring of 1918 the following tests were made.

Pig No. 343, weight 48 pounds, was given twice daily in peanut meal and bran one and one half ounces of ground green (spring) buckeye leaves, flowers and young stems. Excretions, temperature and general condition of this pig remained normal. Blood counts were also normal.

Pigs Nos. 344 and 345 were given every afternoon for four days an armful of young tender green buckeye. They ate a small amount of it. In the morning they were fed peanut meal and bran. Temperature remained normal: appetite good with no signs of diarrhoea or constipation. Blood counts remained normal. (These tests were made by senior veterinary medical students A. R. Gissendanner and B. W. Murray under my direction.) Tests will be made on hogs and cattle during 1919.

(2) In 1917 tests were made to determine the physiological or toxic action of *Helenium tenuifolium* on horses and dogs.

The results shown (after giving large quantities of the plant to horses) were that it produced distinct drowsiness, slow and weak pulse, slow and deep breathing; slight contraction of the pupil; subnormal temperature; always laxative and sometimes purgative action of the intestines.

On the dog similar action with some nausea and irritation of the stomach.

In 1918, an active principle was extracted from the plant with ether, alcohol and hot water, which produced on horses, cattle and dogs subnormal temperature, slow pulse, slow respirations; laxative action and sometimes diarrhoea. Etherial solutions, made from alcoholic extracts, were tested for anti-pyrine, acetanilid and caffeine—and all were negative. Alkaline etherial solutions were tested for brucine, strychnine, veratrine and cocaine with negative results. Inhalations from floating dust, while grinding dry plants, produced violent sneezing and headache. From these tests and clinical observation of horses and cattle that graze in pastures where this plant grows profusely it appears that there are instances or occasions when horses and mules and cattle eat sufficient to produce a type of forage poisoning that not infrequently

has fatal results. This occurs most commonly in the dry times of summer and fall when pastures are short and water is scarce.

(3) Some tests were made on the efficiency of anthelmintics on chickens. The results showed that :

(1) Santonin was quite ineffective on the intestinal parasites of chickens.

(2) Oil of chenopodium (alone or combined with chloroform) was somewhat effective for killing and removing *Taenia annulatum* from the intestines of chickens.

(3) Oil of turpentine proved to be the most effective for removing the *Taenia annulatum*.

The Farmers' Summer School was held at Auburn July 29th to August 4th, inclusive. There were three hundred and twenty-six farmers in attendance and a majority of the counties of the State were represented. Extraordinary interest was taken in all the lectures, exhibits and demonstrations with tractors, judging all kinds of live stock, etc.

Respectfully submitted,

C. A. CARY,  
Veterinarian.

## REPORT OF RESEARCH CHEMIST

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EMERSON R. MILLER

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Auburn, Ala., Dec. 28, 1918.

Prof. J. F. Duggar, Director,  
Alabama Agricultural Experiment Station,  
Auburn, Ala.

Sir:

Under the Adams fund the writer is engaged in a chemical investigation of the velvet bean, the object being to determine its composition with reference to mineral constituents, fats, carbohydrates, proteins and enzymes. The purpose at present is, also, to study different parts of the plant in the same manner.

The writer will also endeavor to complete the work on the chemical analysis of arsenate of lead, upon which Dr. Anderson had done considerable work, as an Adams Fund Project, in co-operation with the Department of Entomology.

Respectfully submitted,

EMERSON R. MILLER,  
Research Chemist.

## REPORT OF PHYSIOLOGICAL CHEMIST

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C. L. HARE

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Auburn, Ala., Dec. 28, 1918.

Prof. J. F. Duggar, Director,  
Alabama Experiment Station,  
Auburn, Ala.

Sir:

Work in the Department of Chemistry for the year 1918 included study of the effects of peanuts, peanut meal, velvet beans, corn, and tankage upon the carcasses and fat of hogs receiving those products in various proportions in the rations.

In the study of the composition of cotton seed in breeding experiments designed to develop a strain of cotton with seed high in oil, it has been found possible to correlate the percentage of oil and ammonia with the amounts of certain inorganic constituents present in the seed.

The Department is also correlating the physiological changes within the cotton seed with climatic conditions existing during the growth of the plant.

Early publication of results of the latter investigation is contemplated.

Respectfully submitted.

C. L. HARE,  
Physiological Chemist.









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